JOURNAL OF THE
British Interplanetary Society

Edited by G. V. E. THOMPSON

1959–60 VOLUME 17, PART 2 APRIL 1959

The British Space Research Programme

On several occasions during the past eighteen months we have urged in this *Journal* that the British Commonwealth should launch satellites and undertake space research. In doing so, we were merely continuing a campaign that the Society has been conducting since 1933. The fact that these eighteen months since the launching of *Sputnik I* passed without any perceptible progress towards a British artificial Earth satellite is a matter of regret, but we welcome heartily the news that a British Spaceflight Programme is shortly to be instituted.

The Society has always endeavoured to be realistic. We advocate interplanetary travel, but we are always careful to point out the problems and difficulties that are likely to arise. Indeed, sometimes we have been accused of being too pessimistic (our reply is that we have to study all the difficulties to find out the way to overcome them). Our approach to the space research programme must be in the same spirit of reality.

The first observation to be made is that we can neither expect nor advocate a programme on the same scale as those of America or Russia. This is not a question of the availability of scientific man-power—in the present economic and political situation, it is government financial support rather than man-power which is likely to be the limiting factor. Money spent on space research means less roads, less television, less beer, less spent on defence—or at any rate, less of some of these things. There is obviously a limit to the sum which can be diverted for astronautics, and even with the participation of other Commonwealth countries, the amount to be spent will be less than is available in the U.S.A. or the U.S.S.R. However, there is no reason why we should not be able to get better value for our money than they have done.

A limited budget means a limited programme. It is far better for us to do a few things well, than to attempt everything ineffectually. However, the projects which we select should not be restricted to a narrow field of astronautics. Certainly they must not be mere imitations of American and Russian feats, as long as these countries continue to release the scientific knowledge they obtain. Our reason for participation should be to extend man's knowledge and not to break records.

In particular, it would be short-sighted for us to restrict our effort to the launching of satellites; we should include in our plans both planetary probes and manned vehicles. The manned reconnaisance of the Moon may seem far-off to us now—although we should be rash if we prophesied that it would not take place in the 1960s—but manned spacecraft are already on the way. An American may well have circled the Earth in the Mercury space capsule before a British artificial satellite is launched. It is not always best to be first in the field, and we may well profit by American mistakes (we sincerely hope there will be none), but the development of a manned vehicle will take a long time, so the sooner we get started the better. The initial expenditure need not be considerable, and much that must be done is a natural extention of work already in progress at such establishments as the R.A.F. Institute of Aviation Medicine.

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THE VENUS PROBE*

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ABSTRACT

The surface of Venus is hidden by the mantle of white clouds that continuously sweep across her. It is reasonable to suppose that before any spaceship lands upon her surface, a preliminary expedition will try to determine the nature of these clouds, and that of her atmosphere, and also the type of surface underneath. This study is concerned with examining the problems involved and with suggesting some possible solutions. No attempt is made to lay down a detailed design as it is felt that engineering and radio techniques will have changed appreciably by the time that such a venture could be undertaken.

I. INTRODUCTION

MANY papers have been written on the subject of travelling to the Moon or Mars. We have a fairly good idea of what to expect when we go there, but the whole subject of Venus is rather vague. Yet, once man can travel to the Moon and Mars, he will find himself in a position to solve the enigma of Venus. The thought of landing blind on a planet of which nothing is known could hardly appeal to even the most intrepid astronaut. If, however, he knew the nature of these clouds, *i.e.*, whether they were vapour condensations or dust storms,[1] whether the surface was firm or soft, the atmosphere steady or turbulent, he would feel more inclined to try.

This study therefore investigates the means of obtaining such data. It is assumed that suitable artificial satellites are already in being, and that exhaust velocities of 1·75 miles/sec. are obtainable. This puts the study in line with many others, such as those of von Braun[2] and Burgess.[3] The only other optimistic assumption is that the weight and bulk of electronic gear will be down to about half of its present proportions.

The form of the expedition is as follows. An inter-orbital spaceship of 3000 tons all-up mass would depart from the artificial satellite and enter an orbit cotangential to the orbits of the Earth and Venus. On making a close pass to Venus, it would release two winged probes which after due retardation will fall towards Venus and after gliding through the atmosphere for about one quarter of her circumference, crash upon the surface.

Whilst descending they will radio back all relevant information about the atmosphere and the results of radar scanning of the surface. Simultaneously, the parent ship will undertake an intensive photographic and radar scanning programme.

The difficulty here lies in ensuring that the radar and radio signals penetrate the Venusian atmosphere. From experience gained with our own atmosphere it is apparent that the best signals to use will be those with frequencies above 50 Mc. employing a wide bandwidth. It is also suggested that the radio transmissions could be made on more than one wavelength to further increase the likelihood of satisfactory reception.

The possibility of sending a beacon probe beforehand was examined. The first conclusion arrived at was that such a probe could not be sent from the parent ship and the main probes modified in time before their launch. The alternative is to dispatch a rocket from the artificial satellite, and under remote control guide it to Venus, where it would descend through the atmosphere, continuously emitting plain signals on many wavebands. An examination of the technical difficulties involved indicated that they were too severe to be solved by known methods.

II. CHOICE OF ORBITS

To determine the most suitable orbit for the parent ship it was assumed that the orbits of Earth and Venus around the Sun are circular and coplanar. Rocket thrust is only applied for relatively short periods at the beginning and end of each semi-ellipse comprising the flight path and during the period preceding entry into the perturbation manœuvre around Venus, so that the parent ship is coasting over the greater part of the journey.

Starting from and ultimately returning to a circular orbit around the Earth at an altitude of about 1000 miles, the following orbits were examined, the probes being released near the point of closest approach to Venus:

(1) The parent ship departs from the Earth by retarding its own motion around the Sun, and travelling on a semi-elliptical path which carries it close to Venus. During this period, small alterations are made to the path in order to enter a suitable hyperbola around the planet.[5] The parent ship then accelerates into a semi-ellipse, along which it travels out beyond the Earth's

* The following is a résumé of the work carried out by the Design Study Group of the Western Branch of the British Interplanetary Society. The members of the group included S. W. Greenwood, F. R. Forbes Taylor, J. Daniel, J. Corbett and the author.

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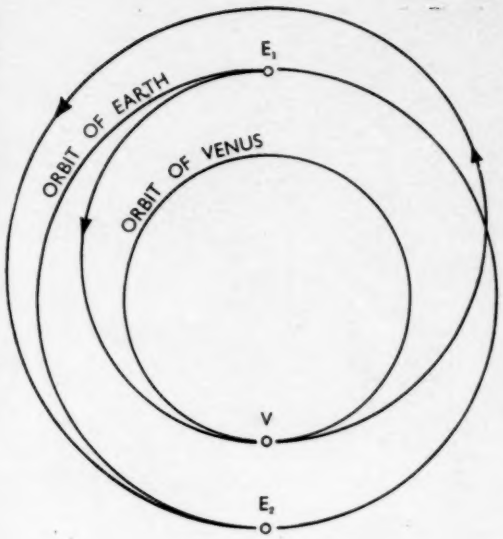

FIG. 1

orbit. It further accelerates at the end of this semi-ellipse and returns by a new one to the Earth (see Fig. 1).

(2) The parent travels on the same semi-elliptical paths as in (1) above, but in the opposite order.

(3) The parent travels on the same semi-elliptical path and enters a circular orbit around the planet. It remains in this orbit until the planets are in suitable relative positions and then returns to Earth on a semi-elliptical path.

The first orbit was chosen as it results in the lowest mass ratio for the parent. The minimum total velocity requirement is estimated to be 6·4 miles/sec. This is made up as follows:

	Miles/sec.
Escape from circular orbit around the Earth ..	2·46
Velocity change made at nearest point to Venus	0·42
Velocity change at points furthest from Sun on return orbit	1·40
Return-to-Earth orbit	2·08
	6·36

Taking a figure of 7 miles/sec. for safety, and an effective exhaust velocity of 1·75 miles/sec., this gives a mass ratio of 52 for the parent ship. The total duration of the voyage is 18 months.

The probes will be launched from just above the atmosphere of Venus. The approach velocity of the parent ship relative to the planet at the point of closest approach is 6·7 miles/sec. It is considered that a velocity of 4·3 miles/sec. is acceptable for a glider entering the Earth's atmosphere or that of Venus. The velocity requirement for each probe at this stage is therefore 2·35 miles/sec. Again taking the effective exhaust velocity as 1·75 miles/sec., this gives a mass ratio of 4 for each probe.

After releasing the probes, the parent ship accelerates to a velocity of 7·1 miles/sec. relative to the planet. It is anticipated that the path of each probe down through the atmosphere is such that the line of sight from the parent ship to the probe will be at all times approximately perpendicular to the surface of the planet. This will be of value in radio communications.

III. PROBE DESIGN

At the beginning of the study, it was decided that just one probe should be used, and that this would be rocket-powered. The purpose of this was that it would then be able to fly for a considerable distance just above the surface of the planet in level flight and obtain more detailed information. However, calculations soon showed that the price of this in terms of weight did not make it worthwhile. For instance, a ten-minute flight at 400 m.p.h. would call for an all-up mass of over 2 tons, whilst that of a simple glider without any power unit would be around 1 ton.

If this result seems at first sight rather surprising, it must be realized that the cause is the necessary increase in wing area when gliding at the high altitudes, rather than the conditions pertaining at the time of the powered flight. In order to keep the maximum skin temperature as low as 1300° C. in the early stages of the glide,[6] a wing loading of 6 lb./ft.² was adopted. By retaining the retarder (see Section IV) it is considered that the peak of the temperature curve normally associated with this type of descent may be avoided. The most useful part of the flight will be that at low altitudes, where the rate of descent will be 800–1000 ft./min. (at subsonic speeds).

Three types of form were considered for these probes:

(1) *Canard.* This would certainly be the most stable, and in view of the fact that it would be unpiloted and uncontrolled in any way, offers reasonable advantages thereby. However, the fuselage necessitated would be of greater bulk than strictly required, and furthermore it would be a weak form of structure in the event of the probe entering the atmosphere at an incorrect angle.

(2) A *saucer*-shaped probe would mitigate some of the worst dangers associated with the canard provided that final orientation to line of flight did not matter. However, when it was decided that the retarder was to be retained, and that some form of fin would be necessary at all times, it was no longer advantageous to have a symmetrical shape.

(3) *Delta.* This would appear to be the best compromise. The dimensions eventually determined were:

Span 20 ft., length 45 ft., wing area 375 ft.²

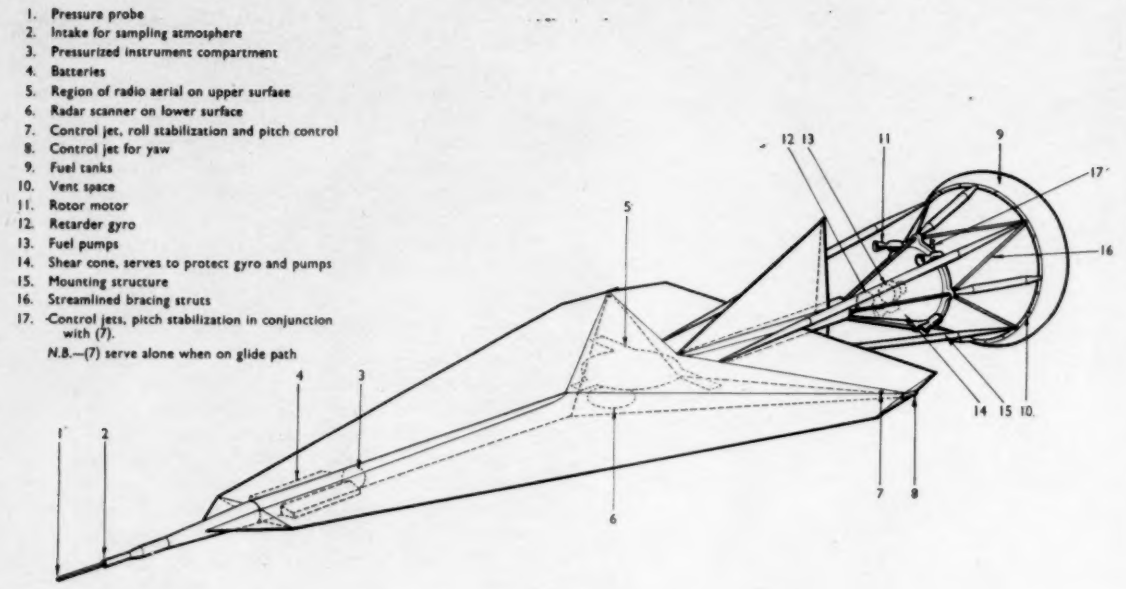

FIG. 2

(see Fig. 2). The mass can be broken down thus:

Wing structure	1,000 lb.
Fuselage and fin	600 lb.
Instrumentation and generators	650 lb.
Total all-up mass	2,250 lb.

The structure of the probe is made from austenitic steels and Nimonic alloys, the skin thickness being 0·020 (26 S.W.G.). A maximum-gust case of 3*g* was considered, giving a peak stress of less than 4 tons/in.^{2}. This is an acceptable level of stress with adequate reserve over excessive creep or fatigue failure, providing that the skin temperature does not exceed 950° C. at mid-chord. The temperature of 1300° C. quoted earlier is a maximum at a point near the leading edge, where the skin will be kept relatively unstressed.

Furthermore, some degree of cooling is provided by a closed steam cycle which gives power to the generator at the time that the probe is flying at the high altitudes. It will be realized that the design of the probe can be tested beforehand by dropping similar missiles down into the Earth's atmosphere.

The question of radar presents one difficult problem. The antennae mounted on the underside of the wing platform will need to be covered by a surface which will have to withstand the high wing temperatures and yet be capable of permitting unhindered transmission and reception or radar beams.

The scannings of the radar and the data collected on the atmosphere, (*i.e.*, dust content, pressure, temperature, composition, wind velocity, ionization and cosmic radiation) will be directly wirelessed back to the parent ship by a transmitter system located on the upper surface of the wing platform. A multi-key vibrator system of 300 signals/channel/second is envisaged.

IV. RETARDER

In order to reduce the speed of the probes that they may drop out of the parent ship orbit and enter the atmosphere, it is necessary to effect rocket thrust.

This is best done by building the rocket motors, propellent tanks, gyro equipment, etc., into a separate element called the retarder. This is attached to the rear of the probe by way of the wing torsion boxes. This gives eight points of attachment which can be arranged with explosive jettison bolts that can be fired at will or by excessive vibration. The retarder will be retained after firing as it will serve as extra drag during the initial phase of slowing down in the Venusian atmosphere.

The basic requirements are:

Mass ratio of probe and retarder unit ..	4
Retarding motor thrust	3 tons
Duration of thrust	7½ min.
Retarder dry mass	0·45 ton
Propellent mass	4·5 ton

The thrust is produced from four small rocket motors mounted behind the probe structure, each being angled so that the jet clears the main structure. Behind them are placed the two propellent tanks. Thus the basic stresses on the mounting are produced by:

(1) Tension loads between probe and retarder motors, with secondary effects arising from roll, yaw and pitch motions.

(2) Compression loads between motors and tanks, together with similar secondary effects.

A diaphragm stabilizes the triangulated support structure at the location of the retarder motors and controls, and is so arranged that the compression struts are kept as short as possible.

The tanks themselves are hemispheres of stainless steel, each with its diaphragm mutually supporting the other. These diaphragms will, of course, be slightly spherical, the radius being determined by the required relative tankage volumes. A 2-in. space will exist between the diaphragms, so as to reduce the possibility of an explosion in the event of a meteorite penetrating both diaphragms. Connecting pillars or webs will transmit the pressure-balancing loads. The arrangement of propellent tanks in this manner is to assist them in their secondary function as an air brake.

However, should the turbulence be such as to set up an unacceptable degree of vibration, an inertia switch will fire off the jettison bolts. The resulting higher Mach number attained by the probe may result in a premature break-up but this is better than its complete destruction by vibration during the early stages.

Eventually the propellent tanks may be expected to heat up, collapse and blow away, leaving the structure and motors to effect drag until the automatic firing of the attachment bolts. The development of such a system can, of course, be carried out in the Earth's atmosphere.

During the firing of the retarder motors and until such time as the probe has entered some way into the atmosphere, it will be essential to maintain the correct angular orientation of the vehicle by auxiliary jets. These would be eight in number, fed from a common source and controlled by the retarder gyro.

In order to reduce the battery requirements of the retarder, the gyro would be run up to full speed with power from the parent-ship batteries just prior to launch.

V. PARENT SHIP

Generally speaking, the main features of the parent ship will be similar to those currently envisaged for an interorbital vehicle, and they are therefore only briefly discussed here. The large mass ratio required leads naturally to the selection of a simple basic design with jettisonable propellent tanks supported by an outrigger structure. At the head of the ship would be the control compartment, spherical in shape and of about 25-ft. diameter. Extending rearwards from this are the pressurized workshops and stores, followed by the unpressurized stores and the probe hangar. Arranged around this central core would be the propellent tanks, mounted between the two main sets of lattice struts built out from diaphragm bulkheads in the ship's central core. At the very rear are the rocket motors.

The control compartment, three tons in mass, would be made from stainless steel with an aluminium outer shell. The only exit would be into the pressurized workshop behind, with an airlock as a safety precaution. The other compartments would be aluminium alloy, as would be the struts supporting the main propellent tank. In the hangar, the probes are carried one behind the other, and when ready for launching, are moved out rearwards. Around this exit, the main motors are suitably arranged on an open gallery in such a manner as to allow their cumulative thrust to be in line with the centre of gravity of the ship even when the propellent is partly spent. Thus certain motors would be automatically cut out as the centre of mass moves transversely across the ship.

The outrigger struts are wire-crossbraced from tie-plates between the motors and from a ring mounted around the control compartment. The propellent tanks cradled between might be of fibreglass basis, and could be held along their length by synthetic fibre suspension nets. The struts, which become redundant as the propellent tanks are disposed of, are detachable and may be jettisoned. In view of this, the secondary jets for control in pitch, yaw and roll will be near the extreme ends of the 200-ft. ship and not in the outrigger struts. The same applies to the radar, wireless and photographic equipment.

The radar and photographic work carried out whilst the ship is in the vicinity of Venus will needs be largely automatic, as the small crew will be occupied with many other functions at the same time.

In conclusion, we would express the opinion that the foregoing sets out the principal problems and gives an indication of one way in which they may be solved. The magnitude of the problem is in many ways less than some of the Martian projects proposed and could therefore be carried out at a comparatively early stage in the development of space travel.

NOTE ADDED IN PROOF

Since the above work was carried out, further orbital studies by Mr. S. W. Greenwood[7] have indicated that a more economical orbit could be used for the parent ship providing that a four-year journey was considered justifiable. By making five ellipses in four Earth years, the velocity requirement drops from 6·4 to 4·9 miles/sec.

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MANNED NAVIGATION AND GUIDANCE IN THE SOLAR SYSTEM*

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ABSTRACT

Inertial guidance techniques are proposed for the mid-course phases of manned interplanetary voyages. Star-trackers stabilize the orientation of a platform to the fixed stars, and the periods of motor operation are monitored by accelerometers. During periods of free fall, a digital computer predicts the trajectory of the vehicle. The gravity field is deduced from the configuration of the solar system, the co-ordinates of the planets, etc. being pre-recorded on magnetic tape or film.

I. INTRODUCTION

It is probable that manned journeys in the solar system will be divided into three navigation phases. First the launch into a pre-computed trajectory; second a mid-course phase during which launching errors are measured and corrected; and third the final approach to the destination. The launch phase can use any of the techniques now used in navigation and guidance of ICBM's and satellite vehicles and can be regarded as well developed. Inertial guidance may be the best choice since it is quite self-contained and independent of ground equipment, although radio and radar techniques can by no means be ruled out.[1]

The terminal phase will almost certainly be based on radar contact with the destination since it is unlikely that the necessary high accuracy and information rate can be obtained otherwise. Although complete procedures for the terminal phase have not been developed, the problems are principally of guidance and control, any navigational information being provided by already well-known radar techniques.

It is considered unlikely, particularly for long voyages, that if an inertial guidance system is used it can be made sufficiently accurate to place the vehicle into its trajectory without the need for subsequent correction, and means must therefore be provided to determine the vehicle's trajectory during the mid-course phase and to compute and apply the necessary corrections. This is the mid-course navigation problem and is the main topic of this paper. The position of the vehicle can be fixed at any time, for example by observing the positions of the planets against the star background. Although the position accuracy available from these fixes will probably be adequate, the deduction of an accurate estimate of velocity is difficult. It is suggested that position fixes are continually taken during the mid-course phase and a trajectory based on a least-square fit to these fixes be computed. The accuracy of this derived trajectory improves as the number of fixes increases. The computations involved in this least-square fitting can be complicated, but they are considerably simplified by the use of a digital computer as described in Section VI.

Having determined the trajectory to sufficient accuracy, the required correction must be computed. This also may be difficult, but the use of a predicted trajectory, recorded in pulse form on magnetic tape or film, may provide a simplification. The corrections will take the form of an applied acceleration in a given direction for a given time and this can conveniently be monitored by the same inertial guidance system as was used during the launch phase, stabilized to the frame of the fixed stars.

To provide a high degree of independence and flexibility, it is suggested that the pre-computed planetary configurations also be recorded on film or tape, thereby enabling accurate "dead reckoning" between fixes.

Although the computers suggested in this paper are complex, they should be rugged and reliable if they are digital and by the use of modern techniques such as transistors and printed circuits, should demand little weight, space and power.

II. PERIODS OF ACCELERATION

For conventional high-thrust rockets, most of an interplanetary flight will be under conditions of free fall. During such periods, there is adequate time in which to take planetary fixes and to reduce the results (see Sections V and VI).

These processes are far too slow, however, for monitoring the application of acceleration (strictly, apparent acceleration—"*apax*" for short) by the rocket motors. When in the vicinity of a member of the solar system on which some type of radio or radar system is available, it may be possible to use this system to monitor the boost phases. Similarly, it may be feasible for radar equipment on the vehicle to be employed when near a planet or satellite. Such systems, however, may be considerably restricted in number and in range.

A more attractive, flexible and self-contained system is perhaps inertial navigation (see Ref. 2 for general introduction). In general, accelerometers measure only *components* of apax along their axes and, therefore, they must be stabilized with respect to some frame of reference. In the present case, the obvious choice is the frame of the fixed stars. If the platform carrying the accelerometers

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is stabilized by gyroscopes, it will be subjected to slow drifts depending on the stability of the gyros. The system may be required to operate over long periods of time (weeks or months) and so the gyros used would need to have very low drift rates. Only 0·01°/hr. drift would lead to 1·7° angular error after a week, and this would probably be intolerable. An obvious possibility is to use the fact that the stars are always visible and stabilize the platform directly by telescopes and photocells. If the platform is stabilized exclusively by telescopes and photocells, there may well be steady-state angular position errors caused in the presence of rotation of the vehicle. To avoid this, it may be desirable to introduce relatively low-grade single degree-of-freedom gyros to serve as integrators and eliminate the position errors. Such gyros may also aid the initial alignment of the platform so as to get the stellar tracking system locked-on. In theory, two stars would enable the table orientation to be fixed. A practical difficulty will probably arise due to the fact that the vehicle itself will want to take up any orientation in space—in fact, it may be rotated at a fairly rapid speed in order to simulate gravity. This seems to make it necessary to provide more than two sets of telescopes and photocells, in order to ensure that enough stars are visible at any instant through the openings in the vehicle's skin. The device may, in fact, look like a sort of planetarium projector in reverse, with a dozen or so eyepieces. Then provided enough holes are made in the skin, two or more telescope systems will always be able to lock-on to their allocated stars. The same physical freedom of the vehicle's orientation will require that the gymbal system be fully free and must not "lock." This will imply a four-gymbal arrangement and fairly complicated resolving systems.

One factor which may cause difficulty and which will certainly have to be taken into account, is that of aberration.[3] Due to the vehicle's velocity, the direction of arrival of the light from the stars and planets will be changed. Ignoring relativistic effects, the apparent angular deflection towards the apex of the vehicle's motion is $(v \sin \theta)/c$ radians, where v is the vehicle's velocity, and θ is the angle between the vehicle's velocity vector and the line of sight to the star or planet. Thus, stars immediately in front and behind the vehicle's direction of motion will suffer no aberration. The maximum aberration occurs to the stars lying on the circle whose plane is at right angles to the vehicle's velocity vector. For a vehicle velocity of 50 miles/sec., this maximum aberration can be as large as 1 minute of arc.

This means either that the telescopes must have a continuously adjustable degree of freedom with respect to each other, or that their angular sensitivities are degraded to about $\pm 1'$ arc. The former alternative implies a considerable complication since the aberration is a function of the magnitude and direction of the vehicle's velocity and of the direction of the line of sight. The latter alternative suggests that the alignment accuracy of the stabilized table cannot be better than about $\pm 1'$ arc. This accuracy, however, may be sufficient, since the orientation of the table is only important during the periods of apax when the accelerometers are in use (see below).

It will be noted that the position lines obtained by fixing the apparent positions of the planets against the star background will not be seriously affected by abberration. The only errors introduced are the differential aberrations between the planet and the reference stars.

Accelerometers (plus integrators as necessary) can now monitor the application of apax by the motor thrust. Theoretically, the system could be used to control the take-off, mid-course guidance and terminal guidance (*e.g.*, landing) phases of the expedition. However, in practice it may be desirable to employ radio and/or radar systems where available, either by themselves or in conjunction with the inertial navigation equipment, particularly in the terminal phases.

Although long-term drifts in the orientation of the stabilized platform could be removed by optical alignment to the stars, the accelerometers themselves can still have drifts, *i.e.*, bias errors. If these are left connected, large velocity and position errors could build up during the long periods of free fall (for example, 0·01 ft./sec.^{2} gives a velocity error of 1·1 mile/sec. and position error of 350,000 miles after a week). During such periods, the accelerometers should be disconnected, so that no errors are built up, and subsequently zeroed before the next application of apax. In this technique, therefore, the accelerometers are only used as navigational instruments during the periods of apax.

III. PERIODS OF FREE FALL

So far, no account has been taken of the gravitational fields which will be experienced. Accelerometers are inherently incapable of giving information about the local gravitational acceleration and therefore have to be compensated.

It has been proposed that the inertial navigation equipment be used to monitor the orientation of the vehicle and the components of the apax applied, and to initiate motor cut when the correct velocity and/or position have been attained. Since it is the *real* velocity and position which have to be monitored, and not the apparent quantities, it is desirable to feed in the gravity compensations into the computer, which would then deal with real quantities. Now in general, one or more members of the solar system will have a gravitational attraction on the vehicle which cannot be ignored. The field of the Sun will always have to be allowed for during expeditions in the solar system, and when taking-off from or landing on a planet or satellite, the gravitational field of that body must obviously be accounted for. In many cases, the terminal phases will require gravity compensation for a multiple system, namely a planet

and its major satellite or satellites. During the mid-course phase, it may be necessary to allow for the perturbations of the major planets, such as Jupiter. Therefore, gravity compensation will, in general, be an *n*-body problem and, as such, quite complicated.

It may be argued that by taking planetary fixes periodically (see Section V) the progress of the vehicle can be followed adequately without requiring specific knowledge of the local gravitational fields. In such a system, however, it will not be possible to determine the velocity vector of the vehicle without taking into account the effects of gravitation between fixes. Perhaps if the vehicle is somewhere near a predicted space-time trajectory, a predicted value of gravitational acceleration could be used, but this tends to reduce the flexibility of the navigation system (see Section VIII). Also, it is implied in this system that the frequency of fixes should be high enough to keep both the position and velocity data up-to-date and this may be tiresome. This is perhaps particularly true near the terminal planets when the time factor becomes vital.

It is suggested, therefore, that the gravity compensations are continuously computed as a function of time and the vehicle's position, and inserted with a high degree of accuracy. This will obviously require fairly complex equipment, but it is suggested that the gain in flexibility and the improvement in the dead-reckoning accuracy (and therefore the need of fewer fixes) outweighs this complexity. The general form that such a computer might take is discussed in the next section.

IV. NAVIGATION COMPUTER

Until some form of propulsion is discovered or developed which provides a virtually unlimited supply of energy to the space vehicle, it will be of major importance to travel in trajectories which keep the total energy requirements small. This strongly implies that for a given journey a predicted space-time trajectory will be precomputed (see, for example, page 232 of Discussion in Ref. 4).

A considerable amount of work will be involved in this computation. At very little extra cost and effort it would be possible to produce a digital record on magnetic tape or film of this nominal trajectory in terms of the position and velocity co-ordinates as functions of time. This record of the predicted trajectory can then be used to compare with the vehicle's actual position and velocity and hence the necessary corrective manoeuvres can be deduced to get the vehicle back on to the nominal trajectory.

The precomputation of the predicted trajectory will also involve detailed knowledge of the positions of the members of the solar system throughout the (future) period of the journey. This can presumably be forecast by the current methods of celestial mechanics, probably aided by the use of a digital computing machine. Thus, another natural by-product of the pre-computation could be a tape or film record of the planetary and satellite positions for the duration of the expedition.

It is suggested that the fruits of these labours can conveniently be used (in tape or film form) in a computer carried aboard the space vehicle (see Fig. 1). The record of planetary positions can be used as input to the gravitational compensation circuits, while the predicted trajectory is used as a reference for the vehicle's position and velocity. From knowledge of the positions of the vehicle and of the members of the solar system, the gravity computer would continuously determine the

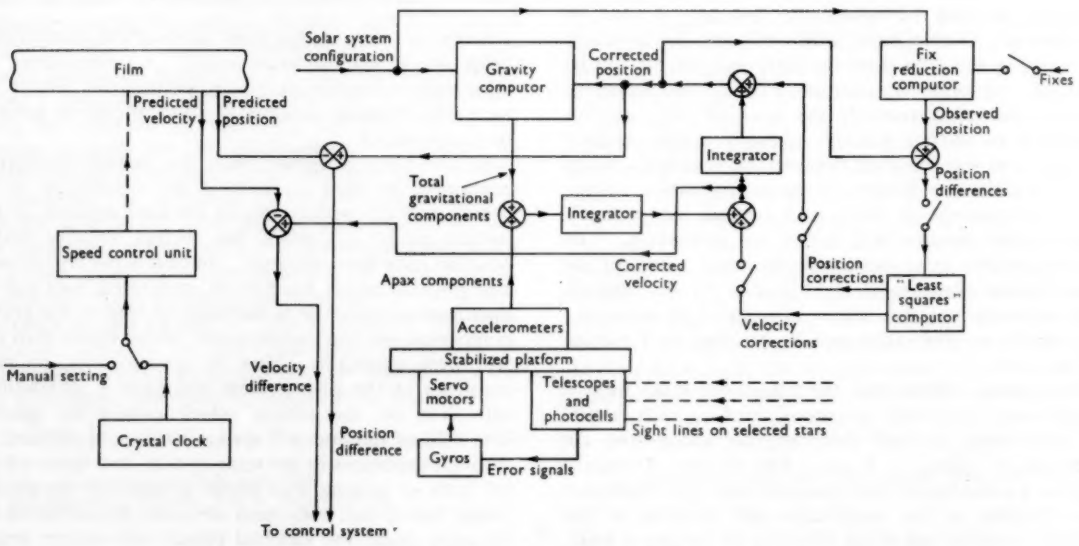

FIG. 1. Block diagram of complete navigation system

total gravitational acceleration components acting on the vehicle. These would be added to the components of apax due to motor thrust, atmospheric drag, etc., as determined by the accelerometer system. The components of total acceleration so obtained, would then be integrated to give the velocity and position of the vehicle continuously. Provision would be made for the vehicle position and velocity so computed to be checked against those determined by the planetary fixes and revised if necessary (see Sections V and VI).

The accuracy of the computations required will be high. For example, for a position error of $\pm$ 1,000 miles in 10^9 miles, an accuracy of 1 part in 10^6 is required. This almost certainly rules out analogue computation. A digital computer, however, could work to this accuracy provided it has sufficient capacity (with a "bit" of 500 miles, a binary counter would require about twenty-one stages to be able to handle a number up to 10^9). For time measurement, a crystal clock should give quite adequate stability. Long-term accuracy of 1 part in 10^7 is relatively easily achievable. This corresponds to about 3 sec. in a year, so that this accuracy is ample even for timing the planetary fixes (see Section V).

A general form of digital computer which may be suitable in the present case is that of a digital differential analyzer (DDA). A DDA represents each of the physical entities involved in a problem by a digital number in a counter or a delay line. Techniques have been developed whereby the computations can be carried out serially, *i.e.*, a limited number of basic arithmetic units can be used to execute a larger number of mathematical operations one after the other. This technique involves the use of storage devices such as delay lines to accommodate the numbers not being operated on at any given instant.

As regards the input data on the planetary configurations and the predicted trajectory, a suitable form of record could be a series of pulses on a magnetic tape or film. These pulses would represent chosen increments in each of the position co-ordinates of the planets and satellites. The *maximum* number of bodies whose co-ordinates will have to be stored in this way may be nine planets, the Moon, the four major satellites of Jupiter, the major satellite of Saturn, the major satellite of Neptune, and possibly the four major asteroids. This is a total of twenty bodies, each requiring three position co-ordinates. The maximum total number of tracks required for the solar system would, therefore, be about sixty. In addition, the tape or film would carry the components of position and velocity of the predicted trajectory and also a timing track. This gives a maximum grand total of about sixty-seven tracks, which would probably require the use of six or seven synchronized films each carrying about ten individual tracks. In practice, however, it will be possible to reduce the total number of tracks without significant loss in accuracy. It may be that only about eight bodies will ever have to be taken into account on a given expedition, including any satellites of the terminal planets. This would reduce the total number of tracks required to about thirty-one, which could possibly be accommodated on three synchronized films.

The frequency with which the planetary configurations would have to be changed in the computer depends on the final accuracy required. The store of planetary configurations will presumably be used to aid the reduction of the planetary fixes. The time accuracy required for these fixes depends on the planet involved. It is suggested in Section V that on the average, the time error should not exceed about $\pm$ 25 sec. if this source of error is to be tolerable. To avoid the undesirable consequence of having to record the planetary configuration *for every* 25 *seconds* (on the average), it could be arranged that fixes are only taken at times when the stored data is most up-to-date. For example, if the film is moved on by, say, one sprocket hole every hour, reading heads can pick off a number of pulses representing the increment in that particular co-ordinate during each hourly period. Thus, every hour the position data in the computer stores can be revised to an accuracy sufficient for reduction of fixes.

If the predicted trajectory is recorded on the same film, then an up-to-date reference will only be available (say) every hour. This may not be a disadvantage during the mid-course phase. In any case, the speed of the data revision (*i.e.*, of the tape feed) can obviously be tailored to suit the requirements at any time.

For computing in real time, the choice of the basic machine rate depends on the accuracy requirements. Suppose it were required to work in 500-mile "bits." The maximum velocity of the vehicle (relative to the Sun, which will presumably be the origin of the co-ordinate system) will be about 50 miles/sec., say. Thus it should be adequate to revise the computed vehicle position every 10 seconds or so. This is extremely slow by modern standards for digital machines, and this leads to an interesting possibility which is discussed in Section VIII.

V. FIXES

In this paper we assume a manned vehicle and that there is a reasonable amount of equipment and freedom to use it. The crew will always be able to see the stars and in general some planets. Photographs or visual observations of the planets visible at the time would yield apparent position of planet against star background and perhaps the apparent angular diameter of the planet. If we assume that the centre of the image can be located to $\pm$ 1″ arc and that the position of this centre can be found relative to the stars to $\pm$ 1″ arc also, then this gives $\pm$ 1·4″ arc total error in the measurements. The vehicle *position* error caused by this is proportional to the distance of the observed planet from the vehicle (see Table I).

TABLE I

Distance of Planet, miles.	Error in Vehicle's Position, miles.
10^7 (quite close!)	± 70
10^8 (~ radius of Earth's orbit)	± 700
10^9 (~ radius of Saturn's orbit)	± 7,000

The intersection of two or more position lines so obtained will then fix the position of the vehicle.

Further errors could arise from errors in timing the observations or from the photographic exposure time. The vehicle position error so caused will be a function of the magnitude and direction of the vehicle's and planet's velocities. The magnitude of the planet's velocity varies from 30 miles/sec. for Mercury down to 3 miles/sec. for Neptune. The vehicle's velocity will be *c.* 10–20 miles/sec. If we allow 20 miles/sec. for the average *transverse* relative velocity, then a timing error of ± 10 sec. leads to ± 200 miles error on average. Thus, for ± 500 miles accuracy, the average tolerable time error is about ± 25 seconds.

If three or four planets can be observed, some method of interpolation will presumably reduce the overall position error.

If it is necessary to take the planetary observations one after the other (*i.e.*, with one instrument), perhaps a "running fix" technique would have to be adopted.

At relatively short ranges from a planet, a measurement of its apparent diameter would yield a useful estimate of its range. At a range of 10^6 miles, the apparent diameters of the planets vary from 5° for Jupiter down to 3·3′ arc for Mercury. If the angular diameter can be measured to, say, 1 part in 1000, the range can be calculated to the same accuracy (*e.g.*, 1000 miles at a range of 10^6 miles).

Summarizing, it looks feasible to assume that position fixes can be obtained to something like ± 1000 miles throughout the trajectory.

VI. TRAJECTORY DETERMINATION FROM FIXES

The only information available during the mid-course phase is the optical observations of the planets and stars and the "dead reckoning" of the navigation computer. From this information it is required to determine the actual trajectory both accurately and quickly—accurately because small errors in the early part of the trajectory can build up to large errors at the destination, and quickly so that corrective action (both to the navigational computer and to the vehicle itself) can be taken early in the voyage. Furthermore, corrections will be small if applied early. We suppose that as soon as the launch phase is over the navigator begins to take a series of fixes at frequent intervals as discussed in Section V. These fixes will be reduced to position coordinates by the Fix Computer in the axis system used by the navigational computer so the fixes provide a series of positions (x_r'', y_r'', z_r'') at times $t_r (r = 0, 1, 2, \ldots)$.

The navigation computer gives a continuous indication of vehicle position, but this will be in error due to inaccuracies in navigation during the launch phase. For example, accelerometer errors will cause a false indication of velocity at the termination of boost which will subsequently be integrated by the navigation computer. However, the errors will be small compared with the true values and the indicated position will be quite close to the true position; in particular the total gravity vectors will be very nearly identical at indicated and true positions. Therefore, the motion of the indicated position relative to the true position is very near a constant velocity in a fixed direction.

Considering motion along the X-axis as an example, if the true position is x_r and the indicated position is x_r', then $\delta x_r = (x_r' - x_r)$ is of the form $Vt_r + D$. In order to determine the actual trajectory we have only to evaluate V and D (for each axis) and correct the velocity store of the computer by V and the distance store by D. This is done by means of the fixes. If, each time a fix is taken, we evaluate $\Delta x_r = (x_r' - x_r'')$ where x_r'' is the position as evaluated by the fix, we would expect Δx_r to lie on the line $Vt_r + D$. This will only be true if the fix is exact, but of course the fix is subject to random errors, so that the sequence of fixes will give points Δx_r which do not lie on the line, but are randomly distributed about it. We therefore evaluate V and D by drawing the best fitting line through this sequence of points by the method of least squares.

It is not difficult to show that the velocity and position errors computed by least squares from the first N fixes are given by:

$$V = \frac{\sum_{r=0}^{N} (\Delta x_r - \overline{\Delta x})(t_r - \bar{t})}{\sum_{r=0}^{N} (t_r - \bar{t})^2}$$

$$D = \frac{1}{N}(\overline{\Delta x} - V\bar{t})$$

$$\text{where } \overline{\Delta x} = \frac{1}{N}\sum_{r=0}^{N} \Delta x_r, \quad \bar{t} = \frac{1}{N}\sum_{r=0}^{N} t_r$$

When sufficient fixes have been taken to obtain the required accuracy, these formulae are computed and the velocity and position corrections are put into the stores of the navigation computer. In practice it may be preferable to compute V and D each time a fix is taken and correct the computer stores so that the most accurate information is always available. It will, of course, be necessary to modify the formulae for V and D to take account of these changes in the reference trajectory. This procedure will also minimize errors due to differences in gravity at indicated and true positions.

It should be possible by these methods to determine the trajectory of the vehicle with considerable accuracy, it being only necessary to take a sufficient number of fixes to reduce the error to the required level.

VII. CONTROL SYSTEM

According to the type of vehicle involved, there may or may not be control of thrust magnitude and thrust direction. Whichever is the case it should be easy to derive a type of control system capable of nulling the differences in position and velocity between vehicle and the predicted trajectory. It was suggested in Section IV that the predicted velocity should be precomputed and stored as well as the predicted position. This is because, although the position difference components might be differentiated to give components of difference velocity, the information rate available is very low and this may well lead to intolerable errors. Whichever way it is done, however, given the components of position and velocity differences, the problem is to find the components of acceleration required to null these quantities.

It is impossible to find a solution to this problem without having in mind the type of vehicle and its propulsive system and it is not proposed to go into details here. In general, however, it may be necessary to apply more than one correction if thrust direction and magnitude cannot be varied at will. For example, it might be chosen to null the position difference with one correction and then to null the velocity difference with a second. In any case, the application of apax for navigational corrections will presumably be under the direct control of the inertial navigation equipment.

VIII. TRAJECTORY PREDICTOR

In normal operation of the navigational computer the input film would be notched along by one hole every hour, say, and the vehicle position recomputed every 10 seconds. Under these circumstances, the film feed and the basic machine pulse rate would be controlled by divided-down pulses originating from the master crystal clock. But if the film and the machine rate are increased by a given factor, then it will be possible to predict the future trajectory of the vehicle on the basis of the present position and velocity (as revised by fixes) and the predicted planetary configurations. Suppose it were possible to speed the film feed up to one notch per second (which will still allow reliable operation of an electromechanical stepping mechanism) and the computation cycle up to once every $\frac{1}{360}$ sec. (*i.e.*, a frequency of 360 cycles/sec.), then in an hour's computation a prediction could be made for about 5 months ahead.

This prediction facility may be most useful. In fact, it might form the basis of a complete navigation and guidance scheme distinct from the system described above. Given the present position and velocity, a prediction could be made of the errors at destination and this in turn could perhaps be used to determine the necessary navigation corrections at any given time. This might be especially valuable if the "destination" is only generally defined. For example, it may be required merely to get into an orbit around the destination planet at a not very critical altitude or orientation and at more or less any time. For such a loose "destination" there is no unique space-time trajectory of approach and it may be far more convenient and economical in fuel to recalculate a new mid-course phase from the actual position of the vehicle rather than forcing it back on to the preconceived trajectory.

Alternatively, a change of plan may be forced on the expedition, particularly if the expedition involves a time of stay on a planet followed by a return journey. In such circumstances, the prediction facility could be used to compute a new predicted trajectory.

Given the facility of being able to enter arbitrary initial conditions of velocity, position and time, this prediction process could, in fact, be used for any celestial "free fall" body of negligible mass. Hence it would be possible for the expedition to plot the future courses of meteors, comets and satellites—any small body in fact which is not already catalogued in the general solar system configuration.

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MINIMUM GRAVITATIONAL LOSSES FOR ROCKET MOTION NEAR A PLANETARY SURFACE*

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ABSTRACT

For a given effective mass-ratio, if a rocket achieves a smaller velocity increment in the presence of a gravitational field than it would in the absence of one, it is said to suffer "gravitational loss" during the period. In general, the gravitational loss depends on the shape of the trajectory and the acceleration regime. The case of take-off from or landing on a planet is considered. Minimum gravitational losses are incurred in a trajectory hugging the surface of the planet, and these are calculated for constant acceleration and constant thrust regimes. An approximate solution only is found for the latter case.

LIST OF SYMBOLS

$\mathbf{a}$, a	Acceleration of rocket due to the thrust of its motors (apax).
u	Effective exhaust velocity from rocket motor.
m	Mass of rocket.
$\dot{m}$	Rate of change of rocket mass (= *minus* the propellent mass rate of usage).
v	Apparent velocity; integral of apax.
R	Effective mass ratio.
$\mathbf{g}$, g	Acceleration due to gravitational field.
$\mathbf{A}$, A	Total (real) acceleration of rocket.
$\mathbf{V}$, V	Real velocity of rocket; integral of real acceleration.
r	Radius of circular orbit (or radius of planetary surface).
$n = a/g$	(In constant apax case).
$V_c = \sqrt{gr}$	Circular velocity at radius r.
$X = V/V_c$	
$\phi =$	$\cos^{-1}(X/\sqrt{n+1})$
$N =$	$\sqrt{(n+1)/2n}$
R'	Effective mass ratio for constant *apax* trajectory.
$x =$	v/V_c.
$\delta x =$	$(x_2 - x_1) - (X_2 - X_1)$.
$a_1 =$	αg. Initial acceleration in constant thrust case.
R''	Effective mass ratio for constant *thrust* trajectory.
$k =$	v/u.
$K =$	V/u.
$\delta k =$	$(k_2 - k_1) - (K_2 - K_1)$.
$\xi =$	u/V_c.

Suffices

1	Initial value.
2	Final value.

I. INTRODUCTION

For a rocket vehicle manoeuvring in the complete absence of a gravitational field, certain simple well-known equations relate the effective mass ratio of the rocket with the velocity increment achieved. This relationship is independent of the time history of motor firing and the motor thrust.

In a gravitational field another acceleration term enters the equation of motion. This field may or may not aid the manoeuvre, but in most practical cases does not. For a given effective mass ratio, if the rocket achieves a smaller velocity increment in the presence of a gravitational field than it would in the absence of one, it is said to suffer "gravitational loss" during the period.

In interplanetary space, well away from the planets or the Sun, the gravitational fields are weak and gravitational losses are small. In manoeuvres near a planetary surface however, a considerable amount of extra rocket energy (*i.e.*, extra propellents) may be required to overcome the effects of gravity during the period of motor firing. The case of take-off from or landing on a planet is considered in some detail. In general, the gravitational loss depends on the shape of the trajectory and the acceleration regime. In this paper, the *minimum* gravitational losses are considered for two regimes, namely constant acceleration and constant thrust. In the first case, an exact solution is found, but it was found necessary to approximate in the case of constant thrust.

II. MOTION IN THE ABSENCE OF GRAVITATION

The acceleration of a rocket vehicle due to the thrust of its motors can be written

$$a = -u\dot{m}/m \qquad .. \qquad .. \qquad (1)$$

The quantity given by Equation (1) is called the "apparent" acceleration ("*apax*" for short). If the exhaust velocity is assumed constant, the apax may be integrated directly to give the well-known formula for the increment of apparent velocity:

$$v_2 - v_1 = u \log_e(m_1/m_2) = u \log_e R \qquad .. \qquad (2)$$

This formula does not assume anything about the time history of m or $\dot{m}$ and is quite general in this sense. It does assume, however, that the thrust is always tangential to the trajectory.

III. GENERAL DISCUSSION OF GRAVITATIONAL LOSS

If we ignore the aerodynamic effects of any atmosphere which may be present, the only acceleration acting on the rocket during powered flight apart from the apax $\mathbf{a}$ produced by the motor, is that due to the gravitational field $\mathbf{g}$. The total acceleration of the vehicle is therefore

$$\mathbf{A} = \mathbf{a} + \mathbf{g} \qquad .. \qquad .. \qquad (3)$$

* Manuscript received 29 March, 1958, and in revised form 10 May, 1958.

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A is called the "real" acceleration since it is measured relative to the centre of gravitational attraction. This acceleration, when integrated, gives the real velocity **V** of the vehicle, and it is this velocity which has to reach certain values for certain manoeuvres. For example, the real velocity must reach the escape velocity in order that the vehicle has sufficient kinetic energy to overcome a planet's gravitational field and therefore escape into interplanetary space.

It will be appreciated that gravitational loss cannot be defined directly in terms of accelerations, since some of the real acceleration vector **A** may merely produce lateral acceleration ("*latax*" for short) which does not alter the magnitude of the real velocity **V** but only its direction. The definition of gravitational loss given in Section I implies that the loss (or gain) is dependent on the following factors:

(*i*) It assumes that in the case where there is no gravitational field, no latax is produced by the main motor (by jet vanes or gymballing the motor). In other words, Equation (2) assumes that the thrust is tangential to the trajectory, as was pointed out in Section II.

(*ii*) It depends upon the *shape* of the trajectory, partly on account of the latax it demands and partly because of the changes of gravitational potential energy along it.

(*iii*) It depends on the apax regime, *i.e.*, on the time history of the motor thrust. At one extreme, if it were possible to apply infinite apax for zero time (*i.e.*, an impulse), there would be zero gravitational loss. At the other extreme, a vertical rocket producing only just enough thrust to balance its weight would not move, and all the chemical energy of the propellents would be dissipated into kinetic energy of the exhaust.

IV. TAKE-OFF FROM OR LANDING ON A PLANETARY SURFACE

In the case of take-off from or landing on a planet, the trajectory that incurs the *minimum* gravitational loss is a horizontal one that hugs the planet's surface. On such a trajectory, none of the propellent energy is devoted to increasing the potential energy of the rocket. This is a desirable state of affairs, because for conventional "chemical" high-thrust rockets which use their motors for short periods only, the main objective during powered flight is to increase the *kinetic* energy of the rocket as far as possible, increases of potential energy being of little use in general. A certain amount of latax is required in such a "horizontal" trajectory, since this is really a circular orbit of radius equal to the planetary radius. This latax however, is provided by part of the gravitational acceleration. This again is desirable, since the vertical component of the motor apax need be only just great enough to support the rocket's "effective" weight, which is the normal weight less the centrifugal mass-acceleration due to motion in a circle.

If V is the magnitude of the tangential velocity in such an orbit, the equation of motion is obviously:

$$\left(\frac{dV}{dt}\right)^2 = a^2 - \left(g - \frac{V^2}{r}\right)^2 \quad .. \quad .. \quad (4)$$

The solution of Equation (4) is studied in the following sections for two types of apax regime, both being possible in a practical project. They are (*i*) constant apax, and (*ii*) constant thrust. The former will involve some form of thrust control to counteract the change of mass of the vehicle as the propellents are used up. This may be desirable if the vehicle has human beings aboard, in order to avoid excess accelerations. The latter requires no thrust control (except possibly a simple thrust stabilizing system) but leads to high accelerations as the vehicle's mass becomes small. This form of apax regime is perhaps more suited for unmanned, instrumented vehicles.

V. HORIZONTAL TRAJECTORY: CONSTANT APAX

Let the constant apax produced by the motor be

$$a = ng \quad .. \quad .. \quad .. \quad (5)$$

then the equation of motion (4) becomes

$$\frac{1}{g^2}\left(\frac{dV}{dt}\right)^2 = n^2 - \left(1 - \frac{V^2}{gr}\right)^2$$

Writing $V_c = \sqrt{gr}$, the circular velocity at radius r and $X = V/V_c$, this becomes

$$\frac{r}{g}\left(\frac{dX}{dt}\right)^2 = n^2 - (1 - X^2)^2$$

Whence

$$t\sqrt{\frac{g}{r}} = \int_{X_1}^{X_2} \frac{dX}{\sqrt{n^2 - (1 - X^2)^2}}$$

where X_1 is the initial value of X (when $t = 0$), X_2 is the final value of X (when $t = t$) and $X_2 > X_1$.

It will be noted that the integrand is an even function of X, *i.e.*, $f(X) = f(-X)$.

If the initial and final velocity ratios have particular values $X_1 = i$, $X_2 = j$, say (where $j > i$), it follows that the integral would have the same value if $X_1 = -j$ and $X_2 = -i$. Hence the analysis can be applied to decelerating (*i.e.*, landing) rockets as well as accelerating (*i.e.*, taking-off) rockets.

We have:

$$t\sqrt{\frac{g}{r}} = \int_{X_1}^{X_2} \frac{dX}{\{(n + 1 - X^2)(n - 1 + X^2)\}^{1/2}}$$

Put $X = \sqrt{n+1}\cos\phi$; $dX = -\sqrt{n+1}\sin\phi\, d\phi$

When $X = X_1$; $\phi = \phi_1$ and when $X = X_2$; $\phi = \phi_2$.

The solution then takes the form

$$t\sqrt{\frac{2ng}{r}} = \int_{\phi_2}^{\phi_1} \frac{d\phi}{\{1 - [(n+1)/2n]\sin^2\phi\}^{1/2}}$$

This is an elliptic integral of the second kind. Writing $N = \sqrt{(n+1)/2n}$, then:

$$t\sqrt{\frac{2ng}{r}} = \int_0^{\phi_1} \frac{d\phi}{\sqrt{1 - N^2\sin^2\phi}} - \int_0^{\phi_2} \frac{d\phi}{\sqrt{1 - N^2\sin^2\phi}}$$

$$= F(\phi_1, N) - F(\phi_2, N) \quad .. \quad .. \quad (6)$$

It is required to find the relationship between the real velocity (V) and the effective mass ratio (R') at any instant, so as to compare with Equation (2). Since a = constant in the present case, Equation (1) can be integrated directly to give:

$$t = \frac{u}{a}\log_e R' = \frac{u}{ng}\log_e R' \quad .. \quad .. \quad (7)$$

From (6) and (7),

$$F(\phi_1, N) - F(\phi_2, N) = \sqrt{\frac{2}{n}}\,\frac{u}{V_c}\log_e R' \quad .. \quad (8)$$

In order to compare this with the case where there is no gravitational field, consider the effective mass ratios R' and R equal. From Equations (2) and (8), with $R = R'$

$$F(\phi_1, N) - F(\phi_2, N) = \sqrt{\frac{2}{n}}\left(\frac{v_2}{V_c} - \frac{v_1}{V_c}\right)$$

Hence, writing $\frac{v}{V_c} = x$

$$x_2 - x_1 = \sqrt{\frac{n}{2}}\{F(\phi_1, N) - F(\phi_2, N)\} \quad .. \quad (9)$$

For equal effective mass ratios with and without the gravitational field, the deficiency in real velocity due to the gravitational loss is given by

$$\delta x = (x_2 - x_1) - (X_2 - X_1) = x_2 - X_2 \text{ if } x_1 = X_1$$

i.e., we have the same initial velocity ratios with and without the gravitational field.

$$\therefore \delta x = x_2 - X_2$$

$$= \sqrt{\frac{n}{2}}\{F(\phi_1, N) - F(\phi_2, N)\} - (X_2 - X_1)$$

This clearly depends upon both X_1 and X_2 so to avoid complication we put $X_1 = 0$, *i.e.*, consider a take-off manoeuvre from rest. The gravity losses for any other initial velocity ratio (X_1) can easily be deduced from the results so obtained, by subtracting the δx corresponding to X_1 from that corresponding to X_2 (this particular case also applies to a landing rocket, where the values of X_1 and X_2 are interchanged with change of sign, so that X_1 becomes a negative quantity and $X_2 = 0$).

Thus, with $X_1 = 0$, $\phi_1 = \pi/2$ and

$$\delta x = \sqrt{\frac{n}{2}}\left\{F\left(\frac{\pi}{2}, \sqrt{\frac{n+1}{2n}}\right) - F\left(\cos^{-1}\frac{X_2}{n+1}, \sqrt{\frac{n+1}{2n}}\right)\right\} - X_2 \quad .. \quad (10)$$

In Figure 1, δx is plotted against X for various values of n. The quantity δx is to be added to the value of

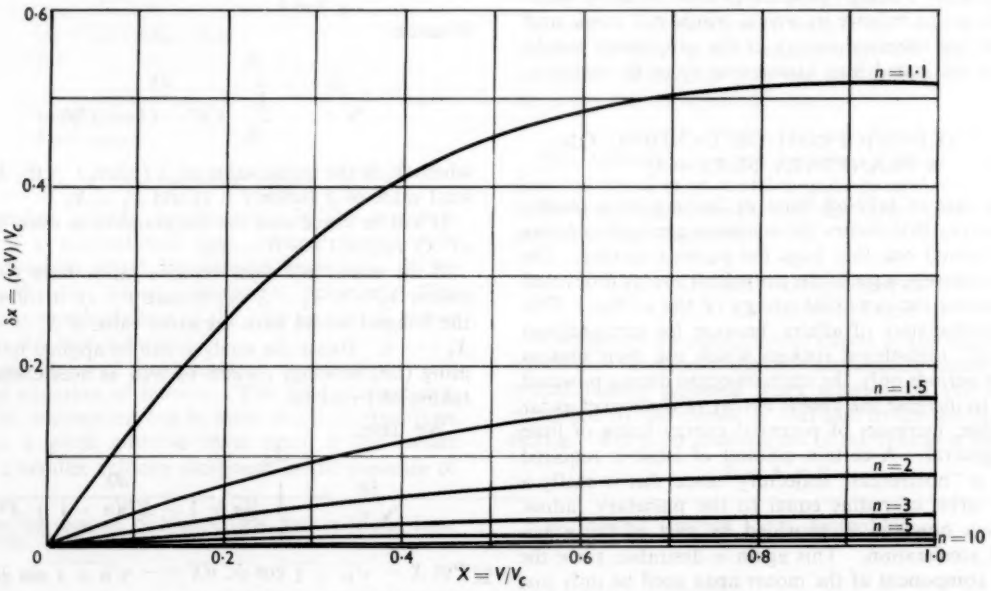

FIG. 1. Gravitational loss factor (constant acceleration)

velocity ratio which it is desired to achieve. The resulting increased velocity ratio is then the one to use in Equation (2) to determine the effective mass ratio required. For example, suppose it were required to achieve a velocity equal to 0·8 × (circular velocity) with a constant acceleration of 1·5 g. Then Fig. 1 gives $\delta x = 0{\cdot}16$ so that the final velocity to use in Equation (2) is $v = 0{\cdot}96\ V_c$.

VI. HORIZONTAL TRAJECTORY; CONSTANT THRUST

If the motor thrust (ma) is constant, then from Equation (1) this implies that the propellent mass flow ($-\dot{m}$) is a constant if the exhaust velocity (u) is also constant. Let the initial acceleration of the vehicle be $a_1 = \alpha g$, then from Equation (1):

$$a_1 = -u\,\frac{\dot{m}}{m_1} \qquad .. \qquad .. \qquad (11)$$

From (1) and (11), $a = R''\,a_1 = R''\,\alpha g$ .. (12) where R'' is the mass ratio in the constant thrust case under gravitation.

In the absence of gravitation, Equation (2) gives

$$R = \exp\left(\frac{v}{u} - \frac{v_1}{u}\right) = \exp(k - k_1) \quad .. \qquad (13)$$

where we have written the instantaneous velocity ratio $k = \frac{v}{u}$. But we are interested in equal effective mass ratios with and without the gravitational field, so with $R'' = R$, Equations (12) and (13) give:

$$a = \alpha g \exp(k - k_1) \quad .. \qquad .. \qquad (14)$$

The equation of motion (4) now becomes

$$\frac{1}{g^2}\left(\frac{dV}{dt}\right)^2 = \alpha^2 \exp 2(k - k_1) - \left(1 - \frac{V^2}{V_c^2}\right)^2 \qquad (15)$$

If we write $K = \frac{V}{u}$, then

$$\frac{dV}{dt} = \frac{dv}{dt}\cdot\frac{dV}{dv} = a\frac{dK}{dk}$$

Hence if we also write

$$\delta k = (k - k_1) - (K - K_1)$$
$$= k - K \text{ if } k_1 = K_1 \text{ (\textit{i.e.}, for common initial velocities)}$$

we obtain (using 14),

$$\frac{dV}{dt} = \alpha g e^{(k - k_1)}\left\{1 - \frac{d}{dk}(\delta k)\right\} \quad .. \qquad (16)$$

Equations (15) and (16) then give

$$\frac{d}{dk}(\delta k) = 1 - \left\{1 - \frac{1}{\alpha^2} e^{-2(k - k_1)}\left(1 - \frac{V^2}{V_c^2}\right)^2\right\}^{\frac{1}{2}} \qquad (17)$$

It has not been found possible to solve (17), but an approximate solution can be obtained by writing $V = v$ on the right-hand side. This is a reasonable approximation since it means that instead of having the correct instantaneous value for the centrifugal acceleration, the value used is too great approximately by a fraction

$$2\frac{\delta v}{v} = 2\frac{\delta k}{k}$$

Since the centrifugal acceleration is aiding the motion, the gravitational loss obtained via this approximation will be slightly too small. With this approximation, (17) becomes

$$\frac{d}{dk}(\delta k) = 1 - \left\{1 - \frac{1}{\alpha^2} e^{-2(k - k_1)}(1 - \xi^2 k^2)^2\right\}^{\frac{1}{2}}$$

where we have written $\xi = u/V_c$.

Since $(k - k_1)$ is positive and for realistic cases $\alpha > 1$, the right-hand side can be expanded to give

$$\frac{d}{dk}(\delta k) = \frac{1}{2\alpha^2} e^{-2(k - k_1)}(1 - \xi^2 k^2)^2 +$$
$$+ \frac{1}{8\alpha^4} e^{-4(k - k_1)}(1 - \xi^2 k^2)^4 +$$
$$+ \frac{1}{16\alpha^6} e^{-6(k - k_1)}(1 - \xi^2 k^2)^6 +$$
$$+ \frac{5}{128\alpha^8} e^{-8(k - k_1)}(1 - \xi^2 k^2)^8 + \ldots.$$

Hence, integration gives

$$\delta k = \frac{1}{2\alpha^2} I_2 + \frac{1}{8\alpha^4} I_4 + \frac{1}{16\alpha^6} I_6 + \frac{5}{128\alpha^8} I_8 + \quad .. \qquad (18)$$

where

$$I_p = \int_{k_1}^{k_2} e^{-p(k - k_1)}(1 - \xi^2 k^2)^p dk$$

Write $z = k - k_1$; $dz = dk$, then z is always positive and

$$I_p = \int_0^{k_2 - k_1} e^{-pz}\,[1 - \xi^2(z + k_1)^2]^p dz \quad .. \qquad (19)$$

This could be evaluated by a series of Incomplete Gamma functions, but the I_p are obviously functions of ξ, k_2 and k_1. This means that $\delta k_{(k_1 \to k_2)}$ is a function of *four* parameters, *viz.*, α, ξ, k_2 and k_1. In this paper, we simplify matters by putting $k_1 = 0$. This means that we are only evaluating the case of *take-off from rest*. The more general evaluation will follow the same lines, and this is left as an exercise for the reader.

With $k_1 = 0$, the integrals become:

$$I_p = \int_0^{k_2} e^{-pk}(1 - \xi^2 k^2)^p dk \qquad .. \qquad (20)$$

The integrals (20) can be evaluated by a series of Incomplete Gamma functions as follows:

Let $y = pk$; $dy = p.dk$, then

$$I_p = \int_0^y e^{-y}\left[1 - \left(\frac{\xi^2}{p^2}\right)y^2\right]^p \frac{dy}{p}$$

$$= \int_0^y e^{-y}\left\{\frac{1}{p} - \binom{p}{1}\frac{\xi^2}{p^3}y^2 + \binom{p}{2}\frac{\xi^4}{p^5}y^4 - \ldots\ldots \ldots\ldots +(-1)^p \frac{\xi^{2p}}{p^{2p+1}}y^{2p}\right\} dy$$

But $$\int_0^\beta y^{t-1} e^{-y}\, dy \equiv \Gamma_\beta(t)$$

$$\therefore I_p = \frac{1}{p}\Gamma_{pk}(1) - \binom{p}{1}\frac{\xi^2}{p^3}.\Gamma_{pk}(3) + \binom{p}{2}\frac{\xi^4}{p^5}.\Gamma_{pk}(5) - \ldots\ldots \ldots\ldots +(-1)^p\frac{\xi^{2p}}{p^{2p+1}}.\Gamma_{pk}(2p+1) \quad .. \quad (21)$$

Values of δk have been computed from (18) and (21) for various values of α, ξ, and the desired final velocity. The results are shown in Fig. 2, which is explained as follows. Although δk is a function of three variables, it has been found possible to plot it on one graph because the results do not vary much with final velocity, *provided* the final velocity is a substantial fraction of circular velocity. In fact, no extra velocity deficit is incurred in exceeding circular velocity $V = V_c$, *i.e.*, $X = 1$. Thus it is convenient to represent the final velocity by the parameter $X = V/V_c$, as shown in Fig. 2.

The quantity δk is to be added to the value of the velocity ratio which is desired. The resulting increased velocity ratio is then the one to be used in determining the required effective mass ratio from (2) or (13). For example, suppose $\xi = u/V_c = 0{\cdot}3$, the initial acceleration is $a_o = 1{\cdot}5g$ and it is required to reach circular velocity. Then Fig. 2 gives $\delta k = 0{\cdot}11$, and therefore the final velocity ratio to use in Equation (13) is $(1/0{\cdot}3) + 0{\cdot}11 = 3{\cdot}44$.

The limitations of the results of this section must be appreciated. In the first place, they are approximate

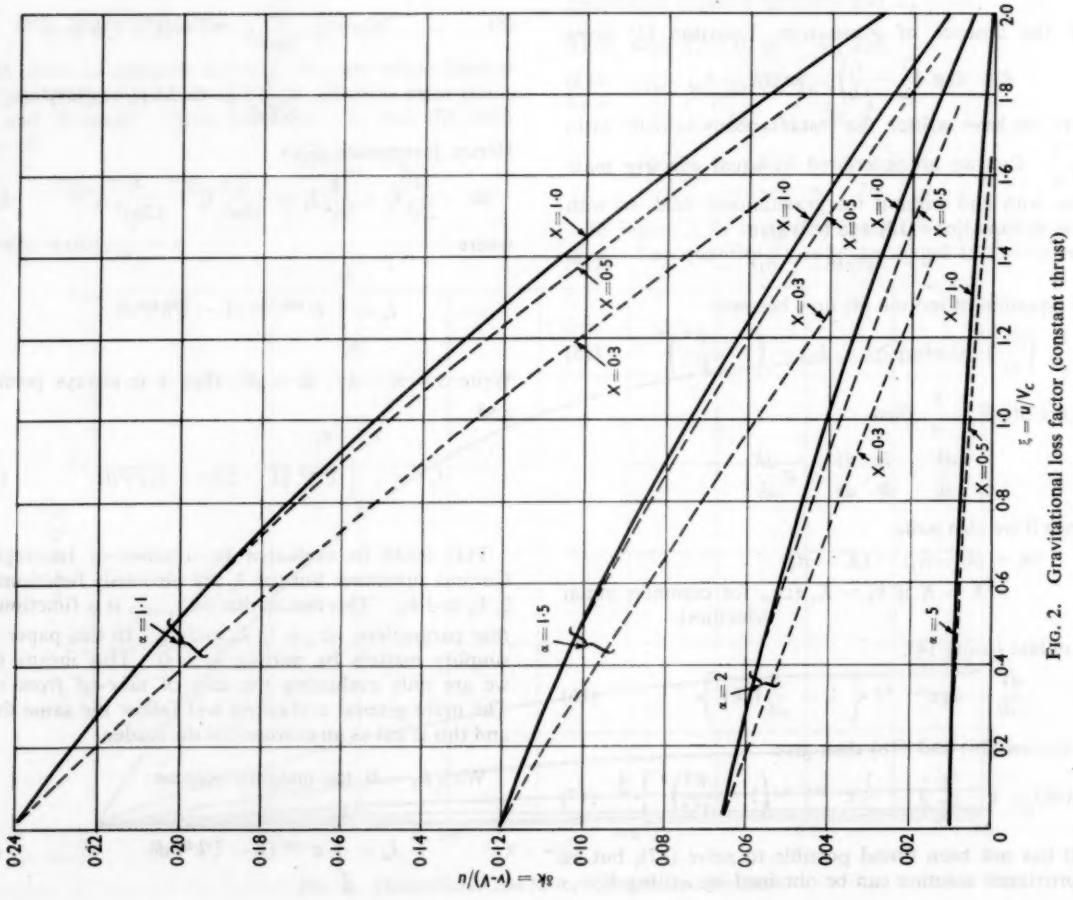

FIG. 2. Gravitational loss factor (constant thrust)

because of the use of v instead of V for the centrifugal acceleration. Secondly, they only apply to the case where the initial velocity is zero and a positive velocity is built up, *i.e.*, the case of take-off. The general formulae for more general cases (including landing manoeuvres) are given in Equations (18) and (19). This second limitation means that the results plotted in Fig. 2 are not directly applicable to the take-off of staged rockets beyond the first stage, since the second and higher stages start off with a non-zero velocity.

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THE PHYSICAL NATURE OF THE SURFACE OF THE MOON*

By GILBERT FIELDER†, B.Sc., Ph.D., F.R.A.S., Fellow

ABSTRACT

Evidence concerning the structure of the lunar rock is reviewed. It is probable that it is vesicular in nature.

DETAILS as small as a mile or so across may be detected on the best lunar photographs of today. It is not possible to obtain pictures showing smaller details, by the use of larger telescopes of smaller resolving powers, for the limit is set by the seeing and not by the optics of such telescopes. Prior information about the *detailed* structure of the Moon's surface would be of vital importance to a landing crew. How, then, are we to get information about the small-scale structure of the lunar rocks?

Fortunately, the light which reaches us from the Moon is not just the same as reflected sunlight: the radiation from the Sun is either reflected, or absorbed and re-emitted by the Moon in some special way which characterizes the lunar surface. Analysis of this radiation tells us many things about the Moon which we cannot appreciate simply by studying photographs.

Observations of the intensity of sunlight reaching the Earth enables an estimate to be made of the intensity of the sunlight which falls unhindered upon the Moon. Measurements may also be made of the integrated brightness of a full Moon and hence its albedo may be estimated. It appears that the Moon does not reflect more than about 10% of the light which is incident upon it. This must mean that either the rocks themselves are unusually dark (the albedos of the common terrestial rocks are appreciably greater than 10%) or that they are of such a nature that a large fraction of the incident light gets trapped in small hollows. Such a state of affairs would obtain, for instance, if there were a layer of loose stones strewn across the surface (Fig. 1).

Unlike other planets, the Moon does not show any limb-darkening: very roughly speaking, the disc of full

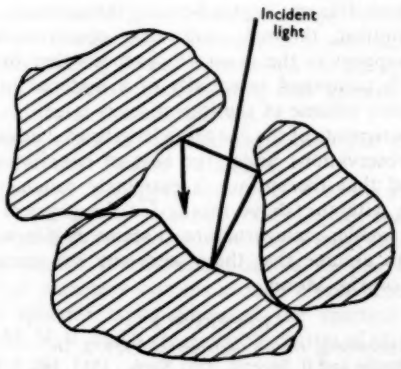

FIG. 1. Trapping of light in rock hollows (vertical section).

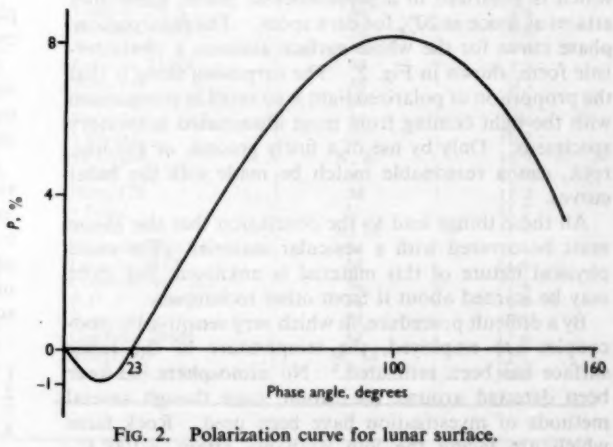

FIG. 2. Polarization curve for lunar surface.

* Abridged version of paper read to the Society in London, 7 December, 1957.

† Coordinator of Lunar Research, Department of Astronomy, University of Manchester.

Moon is uniformly bright. This lends support to the view that there can be no substantial atmospheric mantle around the Moon. The intensity variations of moonlight with the phase angle are difficult to match by means of laboratory models, but a model by Schoenberg,[1] which approaches the observations fairly closely, consists of a spherical surface coated with hemispherical pits, the regions between the pits being convex if viewed from above.

If the albedos of specific spots on the Moon's surface are considered, it is found that some reflect as much as 30–40% of the incident sunlight. In view of their large albedos, the temperatures of such spots must be small, even when the Sun is vertically overhead.

It is well known that maria are darker than the continental regions. In general, maria reflect more green light than do the continents. It is not easy to detect colour differences with the naked eye, but photographic work has shown that the colour of the Moon's surface varies in nature and in intensity from place to place. Miethe and Seegert[2] found that the strong green colour of Mare Tranquillitatis was not detectable until just before full Moon, and they suggested that this unexpected delay in the appearance of colour was due to the presence of large numbers of small shadows cast by unresolvable irregularities in the Sea.

Extensive polarization studies of moonlight have been made by Lyot[3] and by Wright.[4] The full Moon does not polarize any light, but the proportion of polarization, P, defined as

$$P = \frac{I_1 - I_2}{I_1 + I_2} \cdot 100\%,$$

where I_1 is the intensity of light which is polarized in the plane Earth-Moon-Sun and I_2 is the intensity of that which is polarized in a perpendicular plane, sometimes attains as much as 20% for dark spots. The polarization/phase curve for the whole surface assumes a characteristic form, shown in Fig. 2. The surprising thing is that the proportion of polarized light is so small in comparison with the light coming from most illuminated laboratory specimens. Only by use of a finely ground, or ash-like, rock, can a reasonable match be made with the lunar curves.

All these things lead to the conclusion that the Moon must be covered with a vesicular material. The exact physical nature of this material is unknown, but more may be learned about it from other techniques.

By a difficult procedure, in which very sensitive thermocouples are employed, the temperature of the lunar surface has been estimated.[5] No atmosphere has ever been detected around the Moon, even though several methods of investigation have been used. Rock faces which are facing the Sun probably attain +100° C., and the same rock faces have temperatures which might drop lower than −150° C. before sunrise the next day.

G. Fielder: Pic-du-Midi

FIG. 3. Craters in the southern continent of the Moon.

The characteristic manner in which the planetary radiation from parts of the Moon varies during eclipses leads directly to the conclusion that the surface rocks must be very poor thermal conductors. Observations by Piddington and Minnett,[6] and others, of the way in which the radio emission from the Moon varies with the phase angle, support this conclusion (the radio emission comes from different depths beneath the surface).

The optical, thermal, and radio observations lend strong support to the general hypothesis that the lunar surface is composed essentially of a material in which the relative volume of the interstices is large.

Measurements of the changing lengths of shadows, and visual observations under the best of conditions, have indicated that the surface is extremely rough. Taken together with the above results for the physical nature of even smaller-scale structure, it seems as if it would be unsafe to assume that there were any flat stretches of surface on the Moon.

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THE DETECTION OF PLANETS AT INTERSTELLAR DISTANCES*

By M. H. Briggs,† B.Sc., F.R.A.S., Member

ABSTRACT

From recent developments in the theory of planetary origins and the probable relationship between the rate of stellar rotation and the presence of planets, it is suggested that the observed rate of rotation, and hence the spectral type of a star can serve as criterion for the existence of a planetary system. A survey of stellar rotations and spectral types of the nearest stars is given and the probable existence of life on the planets around these stars discussed.

I. INTRODUCTION

HOYLE[1] has proposed modifications of the theory of planetary origins outlined by Weizsäcker[2] and Ter Haar.[3] Using the concept of electromagnetic fields suggested by Alfvén[4] in 1942, Hoyle has shown how the transference of angular momentum from the centre of a condensing, rotating nebula will result in the formation of an equatorial disc of matter that will slowly expand and recede from the central condensation.

By this means it is possible to predict a considerable slowing of the resulting star. The quantitative effects of the formation of an equatorial disc on the period of rotation, however, are difficult to estimate with any accuracy. Observations of the Orion and other nebulae from which stars are known to be condensing, indicate that they have an average rotation of the order of 10^1 — 10^2 cm./sec. As Hoyle has pointed out, such rates would lead to the formation of a very swiftly rotating star. Indeed the star would either be considerably distorted, or torn apart by disruptive forces. As the majority of stars are known to rotate rather slowly, it is obvious that they have been slowed by the production of an equatorial disc from which planets have been formed.

II. STELLAR ROTATION PERIODS

Determination of the rate of rotation of any particular star is only possible by examination of the "profile" of the lines of its spectra. This method is well described and summarized by Jones,[5] who points out the apparent correlation between rotation rate and spectral type. Table I illustrates this relationship.

The percentages of galactic population are derived from the Harvard Draper Catalogue.

It is apparent that approximately 67% of the stars of our galaxy are slowly rotating, which implies that they are accompanied by planets. On the present theory of planetary origins it becomes possible to predict the existence of planetary systems around a star depending upon its spectral type. Stars of the spectral types F, G, K, M, N, R, and S are probably centres of planetary orbits.

TABLE I

Spectral type	Rate of rotation, km./sec.	% of galactic population
O	100–300	0·25
B	100–200	11
A	40– 90	22
F	0– 10	18
G	0– 10	14
K	0– 10	31
M, N, R, S	0– 10	3·75
		Total 100

III. THE NEAREST PLANETARY SYSTEMS

Considering the spectral types of the nearest stars, it is possible to predict that the stars listed in Table II possess planets.

In fact the only star within 13 light-years of the Sun which is unlikely to have a planetary system is Sirius, which is spectral type A and at a distance of 8·6 light-years.

TABLE II

Star	Spectral type	Distance, light-years
Proxima Centauri ..	M	4·2
α Centauri	G, K	4·3
Luyten 726–8	M	5·8
Barnard's star	M	6·0
Wolf 359	M	8·1
Lalande 21185 ..	M	8·3
Ross 154	M	9·3
Procyon	F	10·4
Ross 248	M	10·4
ε Eridani	K	10·7
61 Cygni	K, K	10·9
τ Ceti	K	10·9
Ross 128	M	11·2
ε Indi	K	11·3
Struve 2398	M, M	11·4
Groombridge 34 ..	M	11·6
Lacaille 9352	M	11·9
Cordoba Vh. 243 ..	M	12·4
B.D.-5° 1668	M	12·4
Ross 614	M	12·5
Cordoba 29191 ..	M	12·6
Krüger 60	M, M	12·7
van Maanen's star ..	F	12·8

* Manuscript received 17 September, 1958.

† Dept. of Biochemistry, Cornell University, Ithaca, N.Y., U.S.A.

It would seem that the Sun is situated in a particularly good area for planetary systems, and although interstellar travel is still almost inconceivable, it is not impossible that the future may find that the Earth is most fortuitously supplied with areas for planetary exploration and colonization.

IV. OBSERVATIONAL EVIDENCE OF OTHER PLANETARY SYSTEMS

It is unfortunately impossible for present astronomical instruments to provide any direct evidence of the existence of planets around other stars. However, there are two alternative sources of evidence that can be interpreted as signs of planetary systems. First there are analyses of the dynamics of multiple star systems. Early work of the two stars 70 Ophiuichi and 61 Cygni indicated the presence of small, non-luminous bodies with masses approximately 2–3% of that of the Sun. This work has been confirmed more recently by Rein and Pariiskii[6] and Deich,[7] respectively. According to Kukarkin (quoted in Oparin and Fesenkov[8]) the observed motions of the components of the systems can be interpreted either as a large single body, or as two small bodies with masses intermediate to those of Jupiter and Saturn.

The second type of observation that indicates the presence of other planetary systems involves the small regular variations in the right ascensions of many stars as reported by Holmberg.[9] This worker was able to demonstrate such variations in sixty stars and it is impossible to explain them other than by the existence of planets. It is interesting to note that the stars with these variations were all members of the spectral classes F, G, K, M, N, R, and S.

V. NUMBER OF PLANETS IN THE GALAXY

If about 67% of all stars are attended by planets, it becomes possible to estimate the number of planets within any given collection of stars, such as our galaxy. Modern estimates of the total stellar population indicate that it is somewhere between $1\times$ and 2×10^{11}. Consequently the total number of planetary systems must be of the order of 10^{11} and, assuming that our solar system is not unusual, there must be some 10^{12} individual planets.

VI. ABUNDANCE OF LIFE

In view of the above discussion, the question of the number of life-bearing planets must arise. Although there is no complete agreement amongst biologists concerning the origin of life, the work of Oparin[10] and others in this field indicates that life arises by complex physico-chemical processes on any planet with suitable conditions.

It is reasonably certain that the life-forming processes are completely random and consequently will take a similar time to produce the first simple organisms on all suitable planets. As the Earth seems to have been without life for some 4×10^9 years after its formation, it is probable that life will not exist on any planet with favourable conditions that has not been in existence for the order of 10^9 years.

On the modern theory of planetary origins it is assumed that both a star and its planets will be of approximately the same age for they are formed by the same processes. Consequently the age of a star must be an indication of the age of its planets (if any). The age of a star has been shown by Struve[11] to be related to its absolute luminosity and spectral type. The approximate ages of stars are given in Table III.

TABLE III.—*The Ages of Stars*

Spectral type	Age, years
O	10^5 –10^6
B	10^6 –10^7
A	10^7 –10^9
F	10^9 –10^{10}
G	10^9 –10^{10}
K	10^9 –10^{10}
M, R, N, S	10^{10}

It is of interest to note that the younger stars are those with a fast rotation, which is perhaps an indication that they have not yet completed the planet-forming processes. It is apparent that most stars have existed for a sufficient length of time for life to have developed on their planets, though it should be remembered that life may be unable to develop in multiple star systems owing to radiation variations.

VII. CONCLUSIONS

Modern theory of the origin of planets suggests that the process of planetary formation slows the rotation of stars. The majority of stars appear to have been slowed in this manner and probably have planetary systems. There is some observational evidence that this is true.

The number of planetary systems in the galaxy must be of the order of 10^{11} and the age of most stars supports the belief that life has arisen on their planets.

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British Interplanetary Society

LIMITED (by Guarantee)

FOURTEENTH ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the FOURTEENTH ANNUAL GENERAL MEETING, of the BRITISH INTERPLANETARY SOCIETY will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1, on FRIDAY, 17 July, 1959, at 6.30 p.m. in the evening precisely, for the transaction of the business specified in the Agenda below.

AGENDA

1. To hear the Chairman's Address.
2. To receive the accounts and balance sheet for the period 1 January to 31 December, 1958, and the auditors' report thereon.
3. To elect eight Members of the Council of the Society. In accordance with Article 15, D. J. Cashmore, W. N. Neat, A. E. Slater and S. W. Greenwood will retire at the meeting. Mr. Cashmore, Dr. Slater and Mr. Greenwood offer themselves for re-election.

   In addition, Dr. W. R. Maxwell (a co-opted Member) retires in accordance with the Provisions of Article 18 and also offers himself for re-election.

   If other additional names are nominated and the number of nominations exceeds the number of vacancies, election will be by postal ballot.
4. To consider and, if thought fit, to pass the following as a SPECIAL RESOLUTION:

   (*a*) THAT Articles 5 (*c*), (*d*), (*e*) and (*f*) be and they are hereby re-numbered to 5 (*d*), (*e*), (*f*) and (*g*) respectively.

   (*b*) THAT a new Article 5 (*c*) be and it is hereby inserted reading as follows:

   5 (*c*) ASSOCIATE FELLOWS.

   This shall be open to persons having any relevant scientific, technical or professional qualification set out in the Bye-Laws appropriate to this grade of Membership.

   Election shall be by a majority of the Council, on the application of the Member.

   Associate Fellows shall pay an annual subscription of Three Guineas.

   (*c*) THAT these amendments be effective as from 1 October, 1959.

   If the Membership approves the Council's recommendations set out in the above Special Resolution, certain changes in the Bye-Laws will also be required. The proposed changes to be made by the Council in accordance with the authority vested in them by Article 22 are set out below:

   By-Law 3.

   Form "A" set forth in the Schedule attached to the Bye-Laws dated 1 January, 1951 (reprinted on page 375 of the *Annual Report* for 1950) is now withdrawn and a new form "A" included in place thereof in the draft approved by the Council at its meeting on 6 December, 1958.

   By-Law 6.

   (i) No applicant shall be eligible for admission as a Fellow unless he possesses one at least of the following qualifications:

   (*a*) A recognised University degree in science, mathematics, engineering or medicine, *plus* five years' relevant scientific, industrial or other professional experience.

   (*b*) Corporate Membership of a professional institution in an appropriate field recognised by the Council for this purpose. The following institutions are recognised by the Council for this purpose:

   Institute of Physics
   Institution of Civil Engineers
   Institution of Electrical Engineers
   Institution of Mechanical Engineers
   Royal Aeronautical Society
   Royal Institute of Chemistry.

   Consideration will be given to other institutions of a generally comparable status.

   (*c*) Considerable contributions to the development of astronautics.

   The Council shall also have a discretionary power to elect to Fellowship any person whom they consider to be making an important contribution to astronautics or to the Society.

   Fellows may use the designatory letters "F.B.I.S."

   (ii) No applicant shall be eligible for admission as an Associate Fellow unless he possesses one at least of the following qualifications:

   (*a*) A recognised University degree in science, mathematics, engineering or medicine.

   (*b*) Graduateship of a recognised Professional Institution in an appropriate field recognised by the Council for this purpose.
   The Institutions listed under (i) (*b*) above shall be recognised for the purposes of this Bye-Law also.

   (*c*) Higher National Certificate, or an equivalent.

   (*d*) An examination qualification equivalent to Intermediate B.Sc., or Ordinary National Certificate, *plus* five years' relevant scientific, industrial or other professional experience.

   Applicants for election to Associate Fellowship under Clause (*d*) above must not be less than 25 years of age. Applicants for election under other clauses must be over the age of 21 years.

   Associate Fellows may use the designatory letters "A.F.B.I.S."

   (iii) The decision of the Council as to the eligibility of any applicant in regard to the relevance of his scientific, industrial or other professional experience or qualifications shall be final.
5. General discussion of the affairs of the Society during the past year.
6. Any Other Business.

By Order of the Council,
L. J. CARTER,
Secretary.

A member who cannot be personally present at the meeting may appoint by proxy some other person (who must be a member of the Society) to attend and vote on his behalf, subject, however, to the limitation that a proxy cannot vote except on a poll.

The British Interplanetary Society

LIMITED (by Guarantee)

INCOME AND EXPENDITURE ACCOUNT for the Year ended 31 December, 1958

1957 £	Expenditure.	£ s. d.	£ s. d.
	To Office and Management Expenses—		
	Rent, Rates, Light, Heat,		
326	Cleaning and Insurance ..	520 12 1	
	Salaries and National In-		
1444	surance	1104 9 11	
	Postage, Stationery, Tele-		
1240	phone	1034 16 0	
—	Repairs and Renewals ..	362 10 2	
328	Publicity and Advertising ..	297 3 2	
212	Travelling and Entertaining	213 17 5	
198	Sundry Expenses	196 17 5	
			3730 6 2
3748			
4868	" **Publications**		5632 6 3
552	" **Expenses of Meetings**		864 8 8
	" **International Astronautical Federation—**		
443	Contribution and Expenses		368 19 7
103	" **Income Tax**		52 6 0
	" **Depreciation—**		
132	Furniture and Equipment ..	180 5 3	
—	Library	57 6 0	
			237 11 3
—	" **Transfer to Benevolent Fund** ..		250 0 0
	" **Excess of Income over Ex-**		
—	**penditure**		394 8 0
£9846			£11,530 5 11

1957 £	Income	£ s. d.	£ s. d.
6135	**By Membership Fees**		7856 1 11
369	" **Donations**		395 5 1
	" **Library Subscriptions and Sale of Publica-**		
1356	**tions**		1563 3 6
409	" **Advertising Receipts**		551 17 3
80	" **Royalties**		947 0 1
	" **Income from Investments—**		
		£ s. d.	
44	3½% Defence Bonds	35 0 0	
—	Building Society Interest ..	70 13 8	
208	Bank Deposit Interest	98 1 2	
			203 14 10
76	" **Sundry Receipts**		13 3 3
1169	" **Excess of Expenditure over Income** ..		— — —
£9846			£11,530 5 11

BALANCE SHEET as at 31 December, 1958

1957 £	Capital and Reserves.	£ s. d.	£ s. d.
	Accumulated Fund—		
5346	Balance at 1 January, 1958	4176 17 2	
	Add Excess of Income over		
	Expenditure	394 8 0	
1169	*Less* Deficit for the Year ..	— — —	
			4571 5 2
4177			
1858	**Compounded Subscriptions Reserve** ..		1887 13 6
107	**Income Tax Reserve, 1958/60**		56 11 0
6142	Total of Capital and Reserves		6515 9 8
	Current Liabilities		
76	**Income Tax 1958/59**	102 17 0	
716	**Subscriptions Paid in Advance**	514 13 8	
656	**Sundry Creditors**	1438 0 11	
			2055 11 7
£7590			£8571 1 3

Certified to be a true copy

L. R. Shepherd } *Members of*
G. V. E. Thompson } *the Council*

L. J. Carter, *Secretary*

1957 £	Fixed Assets.	£ s. d.	£ s. d.
	Furniture and Equipment—		
1514	At Cost	1443 19 9	
714	*Less* Depreciation to date ..	893 19 9	
			550 0 0
800			
	Library—		
423	At Cost	530 4 2	
323	*Less* Depreciation to date ..	380 4 2	
			150 0 0
100			
	Investments—		
	3½% Defence Bonds (P.O.		
1000	Issue)	1000 0 0	
	4% City of London Building		
—	Society Deposit Account	2000 0 0	
			3000 0 0
1900	Total of Fixed Assets ..		3700 0 0
	Current Assets.		
	Sundry Debtors and Payments		
399	**in Advance**	87 19 0	
	Cash at Bank—		
4532	Deposit Account	2532 0 0	
732	Current Account	2244 3 0	
27	**Cash in Hand**	6 19 3	
			4871 1 3
£7590			£8571 1 3

REPORT OF THE AUDITORS TO THE MEMBERS OF THE BRITISH INTERPLANETARY SOCIETY LTD.

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit. In our opinion proper books of account have been kept by the Society so far as appears from our examination of those books. We have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account. In our opinion and to the best of our information and according to the explanations given to us, the said accounts give the information required by the Companies Act, 1948, in the manner so required, and the Balance Sheet gives a true and fair view of the state of the Society's affairs as at 31 December, 1958, and the Income and Expenditure Account gives a true and fair view of the surplus of income over expenditure for the period ended on that date.

15, Craven Street, London, W.C.2.
4 *February*, 1959.

K. READHEAD & CO.,
Chartered Accountants.

NEWS AND ANNOUNCEMENTS

B.I.S. NEWS

Benevolent Fund

The Council has recently considered the desirability of establishing some means of alleviating distress caused to members or their dependents by disablement or bereavement, etc., and has decided that this can best be done by the institution of a special fund, to be known as the B.I.S. Benevolent Fund.

This will be organized along much the same lines as the benevolent funds of other professional societies and institutions. Members will elect annually a board of trustees, who will administer the fund and deal with applications for benefit. Until the first election, the members of the Society's Finance and General Purposes Committee will act as the trustees for the fund.

Initially, any member of the Society of more than five years' standing, or his or her dependents, is eligible for assistance from the fund. Any grants made from the fund during its early stages must necessarily be limited, but it is hoped that with the growth of the scheme it will later be possible to extend both the size and scope of the grants.

Benefits from the fund will not be restricted to members in the United Kingdom or British Commonwealth, but will be available to members resident anywhere.

The initial target for the fund is £3000. As is shown in the Accounts on the opposite page, Council have allocated the sum of £250 from the Society's general monies to act as a nucleus for the fund. A letter from the Chairman of Council appealing for voluntary contributions from members is enclosed with this issue of the *Journal*. At a later date arrangements will be made for United Kingdom members to make annual contributions under deeds of covenant, a method which enables the Benevolent Fund to claim income tax refunds from the Commissioners of Inland Revenue.

Donations to the fund from firms engaged or interested in astronautics will also be welcomed; these will be acknowledged individually in the *Journal*. Members, whether in Britain or abroad, are therefore requested to bring this appeal to the notice of their employers.

Election of Members

The following elections were made at the Council Meeting on 3 January, 1959:

Fellows.

REGINALD THORNTON ALLENBY, B.Sc., 25, Hastings Drive, Flixton, Urmston, Manchester.
RICHARD STANLEY WILLIAM BRAITHWAITE, B.Sc., Ph.D., A.R.I.C., 10, Wolseley Road, Crouch End, London, N.8.
PETER HENRY BYLES, M.B.B.S., M.R.C.S., L.R.C.P., 57, Devonshire Road, London, S.E.23.
AMBROSE LEO CRESSWELL, 65, Princess Gardens, Holywood, Belfast, Northern Ireland.
JAMES OSWALD DYKES, B.Sc., A.M.I.E.E., c/o Lloyds Bank Ltd., High Street, Chelmsford, Essex.
VICTOR NIGEL FERRIMAN, A.F.R.Ae.S., 2B, Stamford Avenue, Styvechale, Coventry, Warwickshire.
PETER WILLIAM FITT, B.Sc., 9, Tarratt Road, Yeovil, Somerset.
JAMES FRANCIS HAWTHORNE, 18, Hawthorn Road, Wallington, Surrey.
KENNETH ARTHUR WARNER HERBERT, B.Sc., "Penlee," 35, Wade Drive, Mickleover, Derby.
DENIS HOWE, The College of Aeronautics, Cranfield, Bletchley, Buckinghamshire.
EDWARD CAMERON KIRBY, B.Sc., Collyweston, Stamford, Lincolnshire.
SIDNEY HERMAN KRIMSKY, B.S., 1321 K Street, Sacramento 14, Calif., U.S.A.
ROY LAW, B.Sc., 13, The Poplars, Ocean Drive, Ferring-on-Sea, Sussex.
STEPHEN WALCOTT MACGREGOR-GREER, B.Sc., 604, Mansfield Avenue, Ottawa, 3, Ontario, Canada.
DORIS JULIET MILNER, M.A., 38, Circus Road, Mansions, St. John's Wood, London, N.W.8.
HERBERT MOORES, 61, Charnley Avenue, Sheffield, 11, Yorkshire.
LAWRENCE DOUGLAS PITTAM, "Clevedon," 54, Park View Road, Tottenham, London, N.17.
STANLEY ROSS, Ph.D., 2035, Harvard Street, Palo Alto, Calif., U.S.A.
EUAN CALDWELL SEMPLE, B.Sc., 8, Southfield Avenue, Paisley, Renfrewshire.
JOHN WILLIAM SHELDON, B.S., 119–14, Marshall Drive, West Lafayette, Indiana, U.S.A.
EDWIN JAMES SMITH, 107, Mayfield Road, Hornsey, London, N.8.
JOHN OLIN SNEED, B.Sc., M.E., Ph.D., 768, N.W. 3rd Street, Miami 36, Florida, U.S.A.
ROBERT WILLIAM STUTCHBURY, 2, The Crescent, Wharley End, Cranfield, Bletchley, Buckinghamshire.
NEVILLE RUPERT STUART TITCHENER, 95, Heathcote Avenue, Hatfield, Hertfordshire.
ARTHUR TOMLINSON, B.Sc., 38, Brynorme Road, High Crumpsall, Manchester, 8.
JOHN MICHAEL GAWTHORPE TOMLINSON, B.Sc., "Northfield House," Campsall Road, Askern, Nr. Doncaster.
FREDERICK JOHN WOODLEY, M.R.C.S., L.R.C.P., Maiden Beech, Lyme Road, Crewkerne, Somerset.

Senior Members.

STANLEY BEAVEN, 99, Victoria Street, Crewe, Cheshire.
RALPH FOSTER FAIRLEY, 25, Rosebery Terrace, Consett, Co. Durham.
HECTOR WILLIAM GOULD, 35, Queens Road, Hayes, Middlesex.
PETER HAWKINS, 6, York Gardens, Walton-on-Thames, Surrey.
E. W. HINTON, 51, Buller Road, Thornton Heath, Surrey.
ROGER GLENN KNUTH, P.O. Box No. 2, Station C, Buffalo 9, N.Y., U.S.A.
LEENDERT JOHANNES LOS, "Devonia," 46, Elm Road, Evesham, Worcestershire.
KATHLEEN MAXWELL, 21, Tay Crescent, Glasgow, E.3.
MACOLM CHARLES METCALFE, c/o 38, Main Street, Heslington, Yorkshire.
AUSTIN NEIL RICHMOND, 30, Wade Drive, Mickleover, Derby.

Members.

ARTHUR ADAMS, 34, Manorfield Avenue, Driffield, E. Yorkshire.
JOHN LESLIE BAYLISS, 32, Endhill Road, Kingstanding, Birmingham, 22C.
DAVID JUSTIN LINDSAY BIZZELL, 371, Musgrave Road, Durban, Natal, South Africa.
HARRY BRASSINGTON, 29, Windermere Street, Hanley, Stoke-on-Trent.
STANLEY WILLIAM BURTON, 32, Station Road, Great Warley, Walsall, Staffordshire.
JAMES MILTON CANNON, B.S., Creole Petroleum Corpn., Apartado 889, Caracas, Venezuela.
GEORGE R. CHAMLIN, Continental Chemists Corpn., 2256, West Ogden Avenue, Chicago, Illinois, U.S.A.
NOEL IVAN COCKER, 10, Boston Castle Grove, Rotherham, Yorkshire.
DOUGLAS FERNLEY DENBOW, 176, Rugby Road, Binley, Coventry, Warwickshire.
FRANK VERNON P. DENYER, 79, Aldrich Crescent, New Addington, Croydon, Surrey.
TIMOTHY JAMES DOUGLASS, Hallams Heath, Shamley Green, Nr. Guildford, Surrey.
PAUL FRONTERAS, 27, Porchester Gardens, London, W.2.
PATRICK GIRTON, 10, Dunoon Road, Forest Hill, London, S.E.23.
PETER THOMAS GUTTMAN, 591, Grevillea Avenue, Apt. D., Hawthorne, Calif., U.S.A.
ROBERT HARDY, "West by Nor," Colwell Lane, Totland, Isle of Wight.
JACK BERNARD HAYWOOD, 86, Roundwood Way, Banstead, Surrey.
GERALD RICHARD HOMEYER, 112–44, 38th Avenue, Corona 68, Long Island, N.Y., U.S.A.
GRAHAM JOHN HURLEY, 44, Dew Street, Haverfordwest, Pembrokeshire.
ROGER MICHAEL KEARIN, Residential Centre, Saunders-Roe Ltd., Whippingham Road, East Cowes, Isle of Wight.
FREDERICK LE ROY KELLEY, RFD 1, Concord, Mass., U.S.A.
WOLFGANG BENJAMIN KLEMPERER, Dip. Ing., D.Eng., 738, South Bristol Avenue, Los Angeles, Calif., U.S.A.
THEODORE JOSEPH KULIGOWSKI, B.S., 527, Tyson Avenue, Philadelphia 11, Pa., U.S.A.
DOUGLAS BLAKE LARGE, 7, Deethe Close, Woburn Sands, Bletchley, Buckinghamshire.
EZRA CESAR LEVY, M.S., 520, North Highland Avenue, Los Angeles 36, Calif., U.S.A.
WILLIAM TREVOR LINK, Ph.D., Brookhaven National Laboratory, Accelerator Development Dept., Upton, Long Island, U.S.A.
DAVID LOCKSPEISER, Toad Hall, Summersbury Drive, Chinthurst Lane, Shalford, Surrey.
RODERICK JARLATH MACCONAILL, Wilton Park House, Wilton, Co. Cork, Eire.
ANTHONY JAMES R. MACKAY, Casilla 7, Villa Alemana, Chile.
DAVID EDWARD MARTIN, 188, Harold Road, Clive Vale, Hastings, Sussex.
KEITH WENTWORTH METCALF, 50, Granville Avenue, West Hartlepool, Co. Durham.
MIGUEL ERNESTO MEYER, Goya 1064, Buenos Aires, Argentina.
STANLEY A. MOODY, 149, Lyndhurst Road, London, N.22.
PETER ANTONY MURRAY, 609, Oldpark Road, Belfast, Northern Ireland.
KURT DORON OFER, B.Sc., 14, Gordon Street, Ramot Remez, Haifa, Israel.
MICHAEL JOHN OXLEY, 1915, Bois Franc, Saint Laurent, Montreal 9, P.Q., Canada.
CYRIL JOHN H. PARK, LL.B., M.A., "Brackendale," Middleton St. George, Darlington, Co. Durham.
SAMUEL TURNER PETERS, A.B., 1295, Walnut Avenue, Concord, Calif., U.S.A.
IAN CEDRIC PRICE, 403, Commercial Road, Portsmouth, Hampshire.
DAVID SHER, 339, Quebec Avenue, Toronto 9, Ontario, Canada.
STANLEY THEO SMITH, Pippins Cottage, Church Hill, Totlands Bay, Isle of Wight.
GRAHAM STAFFORD, 121, Barrows Lane, Yardley, Birmingham, 26.
WILLIAM ALAN R. STARK, 24, Bank Street, Glasgow, W.2.
GWENDOLYN STEELBERG STIMSON, 2009, East 102 Street, Seattle 55, Washington, U.S.A.
WALTER EUGENE TENGELSEN, B.S., 9729, Paramount Boulevard, Downey, Calif., U.S.A.
DAVID CHARLES TRUEMAN, 33, Newport Street, Ryde, Isle of Wight.
MALCOLM BRIAN TURNBULL, 5744, Telegraph Trail, Eagle Harbour, P.O., B.C., Canada.
FRANKI LAUREL VAN DER WAL, B.S., 8432, Rindge Avenue, Playa del Rey, Calif., U.S.A.
DEREK VAUGHAN, 25, Central Avenue, Oakdale, Blackwood, Monmouthshire.
ALAN KENNETH WELCH, B.Sc., 184, Carlton Avenue, East, Wembley, Middlesex.
JOSEPH WILLIAM WHITBY, Turks Head Hotel, Castle Donington, Leicestershire.
HERBERT RICHARD WILLIAMS, The Hoo, Warden Road, Totland Bay, Isle of Wight.
GERALD WYATT, 5, Ethelstan Crescent, Belmont, Hereford.
WOODROW LYLE WYATT, M.A., Tower House, Park Village West, London, N.W.1.

JOINT ACTIVITIES

Tenth International Astronautical Congress

Registration Forms for members and other wishing to attend the Tenth International Astronautical Congress were distributed with the April issue of *Spaceflight*; further supplies are available from **The Secretary, B.I.S., 12, Bessborough Gardens, London, S.W.1** (Telephone: TATe Gallery 9371), together with copies of the *Congress Information Bulletin*, which is being issued at intervals.

The programme for the Congress is now taking shape, and is as follows (except where otherwise stated, the venue will be Church House, Westminster):

Friday, 28 *August*; *Saturday morning*, 29 *August*
Registration.

Sunday, 30 *August* (St. Ermins Hotel, Westminster).
Afternoon: Registration.
Evening: Reception.

Monday morning, 31 *August*.
Opening Ceremony.

Monday afternoon, 31 *August*; *Tuesday*, 1 *September*; *Wednesday*, 2 *September*.
Lecture sessions.

Thursday, 3 *September*.
Excursion to Windsor, Stoke Poges and Eton, with river trip.

Friday, 4 *September*.
(i) Lecture sessions.
(ii) Space Law Colloquium (Lincoln's Inn).

Saturday morning, 5 *September*.
Lecture sessions.

Saturday evening, 5 *September*.
Dinner at the Dorchester Hotel, Park Lane.

The following fees are payable:

Registration Fee for attendance at Reception, Opening Ceremony, Lecture Sessions and Space Law Colloquium:

With preprints: £5 5s. 0d. ($15).
Without preprints: £3 10s. 0d. ($10).

Wife's attendance at Reception (no charge made for attendance at Opening Ceremony, Lecture Sessions, and Space Law Colloquium): £1 10s. 0d. ($4.50).

Main Congress Excursion, Thursday, 3 September (including cost of luncheon): £3 3s. 0d. ($9).

Concluding Dinner, 5 September: £4 4s. 0d. ($12).

Various other activities are being arranged, including works visits, tours for ladies and guests, and evening receptions, and all participants will receive a list of these in due course. Attendance at these functions and at the excursion and dinner is optional but it would be helpful if those likely to attend the Congress would indicate as soon as possible in which activities they wish to participate. Members who are unable to be present but who wish to obtain sets of the available preprints may register for this purpose, and this facility will also be available for libraries, firms and institutions.

Hotel and travel reservations may be made through the official agents to the Congress: Thos. Cook & Son Ltd., Berkeley Street, Piccadilly, London, W.1, England, or any of their branches. Hotel Registration forms are obtainable on request from the Secretary or from the office of any I.A.F. Member-Society. The completed forms should be sent direct to Thos. Cook & Son Ltd. as soon as possible. Messrs. Cooks will be maintaining an office in Church House during the whole of the Congress, to deal with further enquiries, complaints, etc.

Special arrangements have been made for the accommodation of students. They may obtain rooms at the Beit Hall of Residence, Imperial College of Science and Technology, Exhibition Road, London, S.W.7, at a cost of 10s. ($1.50) per night. The standard of accommodation is good, and the College is within easy reach of the Congress venue by bus or tube. Meals are also available at the College at a very cheap rate, but must be paid for as taken. Students should send their requests for accommodation to the Warden of the College.

Various other facilities will be available at Church House throughout the Congress, including a temporary Post Office (providing a full postal, telephone and telegraph service), a temporary branch of the Westminster Bank Ltd. (which will be able to handle exchange of foreign currency, travellers cheques, etc.), a reception office, an exhibition, and a bookstall. English, German and French interpreters will be available.

Prospective authors are reminded that the lastest date for submission of manuscripts (three copies) of papers to be presented at the Congress is 1 June, 1959.

Commonwealth Spaceflight Symposium

The I.A.F. Congress announced above will be preceded by a two-day symposium. The theme of this will be Commonwealth Co-operation in a Spaceflight Programme, and it will include communications from the British, South African, Canadian and Indian societies, contributions from B.I.S. members in other Commonwealth countries and a general discussion. Persons resident outside the Commonwealth will be allowed to attend as observers. The Symposium is to be held at Church House, Westminster, on Thursday and Friday, **27-28 August, 1959**. Further particulars will be announced in a later issue of the *Journal* and may also be obtained from the Secretariat.

At the time of writing, the following firms had agreed to present papers at the Symposium: Sir W. G. Armstrong Whitworth Aircraft Ltd., Bristol-Aerojet Ltd., de Havilland Propellors Ltd., *The Financial Times*, Normalair Ltd., Pye, Ltd., and A. V. Roe & Co. Ltd., Members of the staffs of The Queen's University of Belfast; University College, London; and the University of Manchester (Jodrell Bank Station) are also participating. The Guest Speaker from America will probably be Professor S. F. Singer of the University of Maryland.

PERSONAL NOTES

Mr. K. W. GATLAND (VICE-CHAIRMAN OF COUNCIL) has left Hawker Siddeley Aviation Ltd. and taken up an appointment on the editorial staff of The Aeroplane and Astronautics (formerly The Aeroplane), where he will be responsible for astronautical and missile matters.

ASTRONAUTICAL ABSTRACTS

Edited by J. HUMPHRIES and J. FOLEY

1959–60 PART 2

A list of abbreviations of titles of journals was included with the 1954 index and addenda have been published in subsequent issues of the *Journal*. A further addendum is given below:

Brit. Comm. Electr.	British Communications and Electronics.	*Z. Flugwissen.*	Zeitschrift für Flugwissen.
Raktech. u. Raumforsch.	Raketentechnik und Raumfahrtforschung.	*9th Internat. Astronaut. Congr.*	Paper presented at 9th International Astronautical Congress, Amsterdam, 1958.

2—PHYSICS

[*See also* abstracts nos. 219, 220.]

(128) **A study of liquid oxygen blowoff**. D. T. Harrje. *Calif. Inst. Tech., Jet. Prop. Lab. Memo* 20–138, 13 pp. (*Dec.*, 1956).

(129) **On highly dissociated gases**. E. Buchner and R. Strobel. *Z. Flugwissen*, **5** (2), 33–43 (*Feb.*, 1957). (*In German.*) Computation of composition, enthalpy and entropy of dissociating gases is discussed. Method given in detail for diatomic gases and an approximate method also presented. Example of combustion gas shown—approximate method inaccurate for highly dissociated gases.

(130) **Heat transfer to fluids in the region of the critical temperature**. W. B. Powell. *Jet Propulsion*, **27** (7), 776–83 (*July*, 1957). Report of an experimental study using oxygen at supercritical and subcritical pressures. The work shows near the critical temperature a minimum in the heat transfer coefficient which is appreciably lower than the value at lower or higher temperatures. This phenomenon will limit the use of this liquified gas as a heat transfer fluid. (13 *refs.*)

(131) **Thermocouple application for ballistic missiles**. C. T. N. Paludon. *Missiles and Rockets*, **2** (10), 185–7 (*Oct.*, 1957).

(132) **Internal energy of highly ionized gases**. J. Hilsenrath, M. S. Green and C. W. Beckett. *9th Internat. Astronaut. Congr.*, 36 pp. (1958). Gives a method for the computation of thermodynamic properties of gases and gas mixtures containing atoms and atomic ions in chemical equilibrium. Formulae are given for the number of moles, internal energy, density, and specific heat at constant volume in terms of the ionization potentials, ideal gas thermal functions of the constituent atoms and ions, and density of the free electrons. Typical results for oxygen, nitrogen and air are given from 25,000° to 2,000,000° K.

(133) **The recombination of atoms, and other energy-exchange reactions**. O. K. Rice. *9th Internat. Astronaut. Congr.*, 11 pp. (1958). Recombination of atoms (the reverse of molecular dissociation) is important in connection with upper atmosphere processes, shock waves, combustion, etc. The kinetics of the process is discussed, two types of mechanism (collision and complex formation) being compared. Experimental data for various decomposition and recombination reactions are considered in the light of the theory.

(134) **Microwave measurements of electron densities in ionized gases**. W. Low and Y. Manheimer. *9th Internat. Astronaut. Congr.*, 4 pp. (1958). The electron density in thermally-ionized air produced in a shock tube has been calculated from measurements of the attenuation of a microwave beam. Results obtained show that thermal equilibrium is reached in a very short time.

(135) **Cosmic rays and the ionosphere**. A. Ehmert. *Raktech. u. Raumforsch.*, (1), 15–19 (*April*, 1957). (*In German.*) General review, mostly of American rocket work. (13 *refs.*)

(136) **Modern problems of cosmic rays**. E. Lohrmann. *Raktech. u. Raumforsch.*, (1), 20–1 (*April*, 1957). (*In German.*) Nature of primaries and cascade process.

(137) **U.S.A.F. launches artificial meteors**. *Aviation Wk.*, **67** (22), 34 (*Dec.* 2, 1957). Describes discharge, by shaped charges, of pellets from an Aerobee rocket.

(138) **Artificial meteors produce ionosphere**. *Aviation Wk.*, **67** (24), 102 (*Dec.* 16, 1957). Report of radio wave reflections resulting from artificial meteor experiments.

(139) **Radiation measurements from Explorer IV**. J. van Allen, C. McIlwain and G. Ludwig. *9th Internat. Astronaut. Congr.* (1958). Radiation detectors in *Explorer IV* were designed to measure the intense radiation observed with *Explorers I* and *III*. It was found to vary both in quantity and quality with latitude and altitude: at all latitudes the intensity increased with altitude with no indication of a levelling off.

(140) **Scientific results from the Explorer satellites**. A. R. Hibbs. *9th Internat. Astronaut. Congr.*, 26 pp. (1958). Equipment used and results obtained in the measurement of satellite temperatures, micrometeorite densities, and high-intensity radiation by *Explorers I* and *III* (no data are given for *Explorer II*, which failed to achieve orbiting velocity because of a fourth-stage failure). In some part of the orbit the satellites encountered radiation so high that the equipment was no longer able to record it.

(141) **Trapped albedo theory of the radiation belt**. S. F. Singer. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). Cosmic ray action on the high atmosphere produces some upwardly-projected neutrons which decay into protons and these are trapped by the Earth's magnetic field so that they spiral around the lines of force backwards and forwards from pole to pole. The results were not compatible with the altitude distribution of intensity reported by *Explorers I* and *III*, but are compatible with the more reliable data obtained by *Explorer IV*.

(142) **On the method of studying the ionosphere with the help of an artificial Earth satellite**. Ya. L. Al'pert. *Uspekhi Fiz. Nauk.*, **64**, (1) 3–14 (*Jan.*, 1958). (*In Russian.*)

3—CHEMISTRY AND MATERIALS

(143) **Materials and constructions for rockets, missiles and satellites**. B. R. Noton. *9th Internat. Astronaut. Congr.* (1958). Composite or sandwich structures are already in use in civil aircraft and air weapons. Research is now in progress on similar constructions in high-temperature materials for astronautical applications, *e.g.*, silicone plastics, titanium, Inconel X, Multimet, Haynes alloy 25, and ceramic foams.

(144) **Materials for handling fuming nitric acid**. F. H. Beck, M. L. Holzworth and M. G. Fontana. *U.S. Air Force Tech. Rep. No.* 6519, *Part I*, 27 pp. (*March*, 1952). (*Available as PB*109,151.)

(145) **Storage and handling of dimazine**. W. B. Rose. *Jet Propulsion*, **26** (10, Pt. 2), 30S–31S (*Oct.*, 1956). Properties and handling of unsymmetrical dimethylhydrazine.

(146) **Mechanism of inhibiting effect of hydrofluoric acid in fuming nitric acid on liquid phase corrosion of aluminium and steel alloys**. D. M. Mason and J. B. Rittenhouse. *Calif. Inst. Tech., Jet. Prop. Lab. Progr. Rept.* 30–309, 13 pp. (*Dec.*, 1956).

(147) **Some aspects of the stabilization of concentrated solutions of hydrogen peroxide**. W. C. Schumb. *Mass. Inst. Tech., Dept. Chem. Rept.* 30, 14 pp. (*Feb.*, 1957).

(148) **The physical and chemical properties of the alkyl hydrazines**. R. C. Harshman. *Jet Propulsion*, **27**, 398–400 (*April*, 1957). Discusses in particular the methyl hydrazines, which are of the greatest interest as propellents. (15 *refs.*)

(149) **Liquid oxygen plant is mobile**. *Aviation Wk.*, **67** (23), 100 (*Dec.* 9, 1957). Describes a readily moved installation for producing 20 tons per day.

(150) **Heat tolerant metals for aerodynamics**. W. M. Canterbury. *Metal Progress*, **71** (5), 99–100 (*May*, 1957). Outlines briefly metallurgical problems involved in resisting temperatures above 816° C. and speeds above Mach 4.5.

(151) **Vanguard satellite materials detailed**. *Aviation Wk.*, **67** (19), 28 (*Nov.* 11, 1957).

(152) **Non-metallics for missiles**. J. H. Lux and R. L. Noland. **Missiles and Rockets**, **2** (9), 137–8, 141–2, 144 (*Sept.*, 1957).

(153) **Silicoresin B-58 resist Mach 2 heat**. *Aviation Wk.*, **67** (20), 105, 109 (*Nov.* 18, 1957). Describes various applications of temperature-resistant rubber.

4—BIOLOGY AND MEDICINE

[*See also* abstract no. 217.]

(154) **Biological research in satellites?** *Missiles and Rockets*, **2** (2), 23 (*Feb.*, 1957). Comment on the formation of a committee of the Space Medicine Association to propose such experiments.

(155) **The ecosphere in the solar planetary system**. H. Strughold. *Astronautica*, **5** (2), 12–21 (*April*, 1957). (*In Italian.*) Paper presented at Seventh International Astronautical Congress defining limits for life in the solar system.

(156) **Russian dogs probe upper air**. *Missiles and Rockets*, **2** (3), 31 (*March*, 1957). Report of article in *Trud* (a Moscow newspaper) on use of dogs in rocket experiments.

(157) **The problem of weightlessness**. A. E. Slater. *Spaceflight*, **1**, 109–13 (*April*, 1957). The sense of balance, aircraft tests and analysis of results. (8 *refs.*)

(158) **Pressure suits for Soviet pilots have similarities to U.S.** *Aviation Wk.*, **67** (9), 100–2 (*Sept.* 2, 1957). Illustrated description of high altitude suits.

(159) **Laboratory simulates 95-mi. altitude**. I. Stone. *Aviation Wk.*, **67** (15), 62–3, 65, 67 (*Oct.* 14, 1957). Facilities and investigations in a near-vacuum laboratory atmosphere. A suit for operators is also described.

(160) **Nutrition in space flight**. C. A. Adams. *Missiles and Rockets*, **2** (11), 105–7 (*Nov.*, 1957).

(161) **Progress in space medicine**. O. O. Benson. *Missiles and Rockets*, **2** (11), 108, 111–2 (*Nov.*, 1957).

(162) **Human engineering for space vehicles**. G. W. Hoover. *Missiles and Rockets*, **2** (11), 93–5 (*Nov.*, 1957).

(163) **Human factors in space flight**. A. Kahn. *Missiles and Rockets*, **2** (11), 81, 83–4 (*Nov.*, 1957).

(164) **U.S.A.F. full pressure suit is light, permits free movement**. *Aviation Wk.*, **67** (23), 29 (*Dec.* 9, 1957). Illustrated note on suit intended for flight up to 250,000 ft.

(165) **Some physio-psychic experimental data on the effects of accelerations and sub-gravity predictable for man in space**. T. Lomonaco, A. Scano, M. Strollo and F. Rossanigo. *Riv. Med. Aero.*, **20**, 363–90 (*July-Sept.*, 1957). (*In Italian.*) Sub- and zero-*g* tests were carried out on 30 subjects in a 14-metre high tower. Unpleasant feelings were experienced by the majority and movements were slightly uncoordinated. Practice improved coordination. (17 *refs.*)

(166) **Flight experiments about human reactions to accelerations which are preceded or followed by the weightless state**. H. J. von Beckh. *9th Internat. Astronaut. Congr.* (1958). During launching of manned space or orbital vehicles, the crew will be exposed to high accelerative forces, but after burn-out will recover from this stress not in a normal *g* field but in the weightless state. Flight experiments with jet aircraft to simulate these conditions are reported. The need of efficient *g*-protection during these phases is pointed out and several *g*-protective devices are described.

5—AVIATION AND AERODYNAMICS

(167) **A study of motion and aerodynamic heating of missiles entering the Earth's atmosphere at high supersonic speeds**. H. J. Allen and A. J. Eggers. *N.A.C.A. Res. Memo. A53D28*, 62 pp. (*Aug.*, 1953).

(168) **Re-entry test program**. E. Emery. *American Rocket News*, **1** (2), 12, 35, 41 (*March*, 1957). Review of work in wind tunnels, shock tubes and on sleds and description of multi-stage HTV and RTV for free-flight tests.

(169) **The erosion of meteors and high-speed vehicles in the upper atmosphere**. C. F. Hansen. *N.A.C.A. Tech. Note* 3962, 38 pp. (*March*, 1957). Analytic relations for velocity, deceleration, size and relative magnitude of luminosity of meteors are derived in parametric form. Comparison of theory with observed meteor behaviour indicates that large fraction of atmospheric bombardment energy is used in eroding meteor. Erosion from large high-speed vehicles in free-molecule flow is calculated and mass loss is found negligible.

(170) **The stability of bodies of revolution at very high Mach numbers**. A. F. Charwat. *Jet Propulsion*, **27**, 866–71 (*Aug.*, 1957). (9 *refs.*)

(171) **Structural problems in hypersonic flight**. S. B. Batdorf. *Jet Propulsion*, **27**, 1157–61 (*Nov.*, 1957). (12 *refs.*)

(172) **The use of lift for re-entry from satellite trajectories**. A. Ferri, L. Feldman and W. Daskin. *Jet Propulsion*, **27**, 1184–91 (*Nov.*, 1957). (3 *refs.*)

(173) **Some characteristics of the upper atmosphere pertaining to hypervelocity flight**. C. F. Hansen. *Jet Propulsion*, **27**, 1151–6 (*Nov.*, 1957). (16 *refs.*)

(174) **Recent developments in hypersonic flow**. L. Lees. *Jet Propulsion*, **27**, 1162–78 (*Nov.* 1957). (66 *refs.*)

(175) **A survey of heat transfer problems encountered by hypersonic aircraft**. J. R. Stalder. *Jet Propulsion*, **27**, 1178–84 (*Nov.*, 1957). (33 *refs.*)

(176) **Canadians study I.C.B.M. exit, re-entry**. *Aviation Wk.*, **67** (18), 67 (*Nov.* 4, 1957). Brief description of aero-ballistic test installation.

(177) **On the mechanisms of atmospheric ablation**. Sin-I Cheng. *9th Internat. Astronaut. Congr.* 12 pp. (1958). The ablation (loss of material by melting away) of meteoric objects entering the atmosphere is considered; the Lindemann-Dobson and Sparrow-Öpik theories require modification. The deceleration and the presence of a molten layer over the meteoric body results in an unstable liquid-gas interface that leads to direct loss of mass as liquid droplets. Observations tending to verify the proposed mechanism are indicated.

(178) **The supersonic flow about a blunt body of revolution for gases at chemical equilibrium**. F. G. Gravalos, I. H. Edelfelt and H. Emmons. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). Method for determining the shape of the shock and the characteristics of the flow field in the shock layer for supersonic and hypersonic flow at high stagnation temperature in real gases.

(179) **Magnetofluidmechanics: a general lecture.** T. von Karman. *9th Internat. Astronaut. Congr.*, 7 pp. (1958). Author's preference for use of term magnetofluidmechanics instead of magnetohydromechanics; résumé of main principles; applications of the science in astronautics.

(180) **On a class of compressible laminar boundary layers with pressure gradient for an electrically conducting fluid in the presence of a magnetic field.** P. S. Lykoudis. *9th Internat. Astronaut. Congr.*, 13 pp. (1958). Consideration of the general problem of the laminar boundary layer of a viscous, compressible, heat and electrically conducting fluid in the presence of a magnetic field fixed relative to the moving body, with an acting pressure gradient, shows that general similarity solutions for the equations of motion and energy do exist under certain assumptions. Velocity and enthalpy profiles are calculated for different wedge-type geometries and different values of the ratio of the magnetic Reynolds number to the kinematic Reynolds number. The case of hypersonic stagnation flow taking dissociation and catalytic effects at the wall was investigated in detail.

(181) **Magnetofluiddynamics of two interacting streams.** L. G. Napolitano. *9th Internat. Astronaut. Congr.* (1958). (*English Summary.*) The interaction of two electrically conducting streams of different velocities in the presence of magnetic fields has been analysed. Boundary layer type equations are derived for the interaction of semi-finite streams under conditions of constant fluid properties and laminar flow for two special cases where the field is (*a*) stationary with respect to a fixed frame of reference, and (*b*) stationary with respect to the slower stream. Extensions of the analysis to more complex cases are suggested.

(182) **Sud-Aviation SO. 9050 "Trident II."** *Alata*, **13** (140), 16–17 (*Feb.*, 1957). (*In Italian.*) Description and data.

(183) **X-IE goes aloft.** *Missiles and Rockets*, **2** (7), 114–5 (*July*, 1957). Photos.

(184) **Scorpion-Canberra's 70,000 ft.** *Flight*, **72**, 379 (*Sept.* 6, 1957). Account of flight, made with assistance of rocket motor, which achieved a new altitude record.

(185) **Scorpion pushes Canberra to 70,000 ft.** *Aviation Wk.*, **67** (10), 39 (*Sept.* 9, 1957). Report of altitude record assisted by Napier rocket engine.

(186) **Manned rocket aircraft.** F. I. Ordway. *Missiles and Rockets*, **2** (11), 71–8 (*Nov.*, 1957).

(187) **Facility studies re-entry effects.** *Aviation Wk.*, **67** (22), 63–4 (*Dec.* 2, 1957). Describes arc source of energy for high thermal flux experiments with models.

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(188) **Space travel: a selected list of titles for lecturers and students.** *Army Library, Washington, Special Bibliography No.* 2, 11 pp. (*March*, 1956).

(189) **Missilibus ad Astra.** H. Gartmann. *Weltraumfahrt*, **7**(4) 108–16 (*Nov.* 1956). (*In German.*) The Seventh International Astronautical Congress.

(190) **Summary session, Astronautics Symposium, San Diego, Feb, 18–20, 1957.** *Air Force Off. Sci. Res.-TR-57-14, ASTIA AD* 120430, 55 pp. (1957).

(191) **Atlantic research retards Vanguard.** E. Emery. *Amer. Rocket News*, **1** (1), 15, 38, 42 (*Feb.*, 1957). Survey of Vanguard guidance requirements and description of retro-rockets for second stage.

(192) **Review of air and space flight development in the 20th Century.** E. Sänger. *Weltraumfaht*, **8** (1), 1–6 (*Feb.*, 1957). (*In German.*) Short review of progress to date with prognostications for the future.

(193) **Elementary course in mathematics applied to the science of astronautics.** U. Bonfiglioli. *Astronautica*, **5** (2), 36–42 (*April*, 1957). (*In Italian.*) Fundamentals of propulsion, mass ratios.

(194) **Rocket propulsion and space-ships at the VIIth International Astronautical Congress. Pt. I.** J. Corbeau. *Bull. Astr.*, (1), 25–31 (*April*, 1957). (*In French.*) Review of some of the propulsion papers.

(195) **Space power.** D. Cox. *Missiles and Rockets*, **2** (4), 65–9 (*April*, 1957). Military uses of space.

(196) **What scientific knowledge and what economic gain will be gained when the problem of spaceflight is solved?** W. Trommsdorff. *Weltraumfahrt*, **8** (2), 33–8 (*May*, 1957). Largely discussion of astronomical problems.

(197) **Space travel and our technological revolution.** W. von Braun. *Missiles and Rockets*, **2** (7), 75–8 (*July*, 1957). Philosophical considerations.

(198) **Rockets and satellites at Cranfield.** *Flight*, **72**, 153–6 (2 *Aug.*, 1957). An account of the symposium on high altitude and satellite rockets with reports of the papers, discussion and exhibition.

(199) **Rocketing into space.** J. Strong. *Aeroplane*, **93**, 162–4 (2 *Aug.*, 1957). A review of the papers presented at the High Altitude and Satellite Rockets symposium held at Cranfield.

(200) **The Cranfield Symposium.** S. W. Greenwood. *Spaceflight*, **1**, 172–5 (*Oct.*, 1957).

(201) **The International Astronautical Federation.** L. R. Shepherd. *Spaceflight*, **1**, 159–63 (*Oct.*, 1957).

(202) **Astronautics at Barcelona.** A. E. Slater. *Aeroplane*, **93**, 574–5 (18 *Oct.*, 1957). Report of the proceedings of the 8th I.A.F. Congress.

(203) **The astronautical congress.** K. W. Gatland. *Flight*, **72**, 659–60 (25 *Oct.*, 1957). Review of the papers presented to the I.A.F. congress in Barcelona.

(204) **A 'space journey' of the year 1891.** E. Dolezal and R. B. Gostkowski. *Universum Natur. u. Technik.*, **12**, 673–9 (2 *Nov.*, 1957). (*In German.*) On the work of Ganswindt.

(205) **Man in space needed to recapture lead.** E. Clark. *Aviation Wk.*, **67** (20), 26–7, 29–31 (18 *Nov.*, 1957). Comparison of U.S. and Russian military and scientific progress. Includes photographs of rockets in Moscow military parade.

(206) **Astronautics in Barcelona.** *Weltraumfahrt*, **8** (4), 120–2 (*Dec.*, 1957). (*In German.*)

(207) **Soviet Space Agency revealed.** *Missiles and Rockets*, **2** (12), 42, 45–7 (*Dec.*, 1957).

(208) **The 8th International Astronautical Congress in Barcelona.** *Intravia*, **12** (12), 1236–8 (*Dec.*, 1957). An account of the papers presented.

(209) **The technical contributions to the Eighth International Astronautical Congress in Barcelona.** J. Geertsma. *Ruimtevaart*, **6** (5), 2–17 (*Dec.*, 1957). (*In Dutch.*) (*5 refs.*)

(210) **Decisions of the International Astronautical Congress.** A. G. Haley. *Interavia*, **12** (12), 1228 (*Dec.*, 1957). An account of the organization of the I.A.F.

(211) **More or less seriously.** T. von Karman. *Interavia*, **12** (12), 1227–8 (*Dec.*, 1957). A personal impression of the Barcelona congress of the International Astronautical Federation.

(212) **U.S. scientists fear makeshifts in space.** *Aviation Wk.*, **67** (23), 30–1 (9 *Dec.*, 1957). Report of American Rocket Society twelfth annual meeting proceedings.

(213) **Sphere, glider feasible for re-entry.** J. S. Butz. *Aviation Wk.*, **67** (24), 50–2 (16 *Dec.*, 1957). Discussion of alternative re-entry vehicle configurations based on American Rocket Society papers.

(214) **Scientists disagree on man's space role.** G. L. Christian. *Aviation Wk.*, **67** (24), 61, 64 (16 *Dec.*, 1957). General discussion of control of space vehicles and of maintaining human life in space.

(215) **U.S.A.F. forms astronautics directorate.** C. Witze. *Aviation Wk.*, **67** (24), 26–7 (16 *Dec.*, 1957). Report of changes in organization.

(216) **Studies probe man's function in space**. R. Sweeney. *Aviation Wk.*, **67** (26), 45–7, 49 (30 *Dec.*, 1957). Descriptions of scope of investigations of U.S. firms and services branches.

(217) **Problems of ground simulation of long-range spaceflight environmental conditions**. T. C. Helvey. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). Brief description of chambers to study effect of multiple stresses on single-stage rockets under flight conditions, and effect of meteoritic impact on hulls and optical equipment. Also a "human oscillator" to subject prospective crew to high-amplitude, low-frequency vibration; and a protective suit designed to shield the more sensitive parts of the human body so that it receives a uniform isodose of radiation over the whole surface.

(218) **Panatrack: a suggested method of status display for space travel**. E. J. Madden. *9th Internat. Astronaut. Congr.*, 7 pp. (1958). Panatrack is a map projector consisting essentially of a projector inside a globe, which may be positioned manually or automatically to show on a screen or wall any particular field either at rest or in motion.

(219) **Scientific problems in cislunar space and their exploration with rocket vehicles**. S. F. Singer. *9th Internat. Astronaut. Congr.*, 9 pp. (1958). Measurements which could be made in the "cislunar" region between the Earth and Moon: outer atmosphere data, gravitational field effects, magnetic fields, cosmic ray studies, lunar radioactivity, auroral particles, lunar ionosphere and atmosphere, effect of lunar bulge, etc.

(220) **Some consequences of a theory of the radiation belt**. S. F. Singer. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). *J.B.I.S.*, **16**, 558–564 (1957–58). The Moon and other planets would also possess radiation belts if they possess magnetic fields. Manned satellite experiments will only be possible at altitudes below 250 or above 40,000 miles, and interplanetary launchings may have to be made near the poles, where the radiation belt should be absent. Complete shielding is impracticable, but shadow shielding (with a ring) may be possible as the particles are mainly incident perpendicular to the lines of force. Electromagnetic shielding may also be possible. It would be practicable to sweep away the radiation belt with artificial satellites. To check the theory, an artificial radiation belt could be produced by sending up a small electron accelerator in a satellite.

(221) **An interplanetary navigation system**. E. V. Stearns. 9th *Internat. Astronaut. Congr.*, 12 pp. (1958). Describes a prototype system for interplanetary navigation with reference to a specific journey (powered flight from Earth to Venus). Instruments depending primarily on gyroscopic stabilization are expected to have insufficient accuracy over the long-term flights and integrating accelerometer systems are troubled by the non-linear character of the problem. A solar-planetary triangulation system, in which thrust orientation is monitored by an accelerometer-computer system and course-to-go is determined from a steering command computer, is suggested, and estimates of performance are given.

(222) **Technical study of a project for an orbital vehicle of minimum weight**. B. Bergqvist. *Astronautica*, **1** (1), 40–4 (*Jan.*, 1957). (*In Italian.*) (Paper delivered at Seventh International Astronautical Congress.)

(223) **The launching vehicle for the Vanguard satellite**. N. E. Felt. *Astronautica*, **1** (1), 32–9 (*Jan.*, 1957). (*In Italian.*) Description of trajectory and vehicle. (4 *refs.*) (Paper delivered at Seventh International Astronautical Congress.)

(224) **Tasks for the satellites**. H. Faust. *Weltraumfahrt* **8** (1), 9–12 (*Feb.*, 1957). (*In German.*) Review of possible experiments with instrument-carrying satellites.

(225) **Aerodynamics, gas dynamics and heat transfer problems of a satellite rocket**. R. W. Krueger and G. Grimminger. *Rand. Corp. Rept. RA*–15022, 61 pp. (*Feb.*, 1947).

(226) **Effect of Earth's oblateness on the period of a satellite**. L. Blitzer. *Jet Propulsion*, **27**, 405–6, 397 (*April*, 1957). It is shown that in addition to the usual dependence on altitude the period also depends on the inclination of the orbit to the equator. The period increases with orbit inclination. For a satellite at 300 miles altitude circular orbit the difference in periods between polar and near-equatorial orbits is 12 sec. (3 *refs.*)

(227) **The artificial satellite: dream or reality?** B. Midulla. *Astronautica*, **5** (2), 23–31 (*April*, 1957). (*In Italian.*)

(228) **Project Vanguard**. *Missiles and Rockets*, **2** (7), 117–8 (*July*, 1957). General description.

(229) **Stations in space**. J. Gustavson. *Jet Propulsion*, **27** (7), 812–5 (*July*, 1957). A review of proposals for orbital space stations. (4 *refs.*)

(230) **Rundown on the Vanguard vehicle**. *Astronautics*, **2** (1), 62–3, 102 (*Aug.*, 1957).

(231) **The Vanguard instrument package**. H. Friedman. *Astronautics*, **2** (1), 66–9, 104–5 (*Aug.*, 1957).

(232) **Geodesy comes of age with Vanguard**. J. A. O'Keefe. *Astronautics*, **2** (1), 71–3, 92 (*Aug.*, 1957). The uses of satellites in large-area surveys, measuring intercontinental distances, determining the Earth's shape and investigating irregularities in the Earth's gravitational field.

(233) **Three-stage Vanguard vehicles to carry spheres in test firing**. *Aviation Wk.*, **67** (8), 86 (26 *Aug.*, 1957). Advance information on a Vanguard firing (TV-2).

(234) **Troubles boost Vanguard cost**. *Aviation Wk.*, **67** (8), 29 (26 *Aug.*, 1957). Results of failures in test firings.

(235) **The problem of instrumentation of artificial satellites**. *Centro Aeronautico e Atomico Italiano Notiziario No.* 19, 21–7 (26 *Sept.*, 1957). (*In Italian.*)

(236) **Building the Earth satellite vehicle**. *Spaceflight*, **1**, 164–9 (*Oct.*, 1957).

(237) **Sectional satellites**. G. W. Hoover. *Missiles and Rockets*, **2** (10), 135–7 (*Oct.*, 1957).

(238) **The effect of the Earth's oblateness on the orbit of a near satellite**. D. G. King-Hele and D. M. C. Gilmore. *R.A.E. Tech. Note G.W.*475. 67 pp. (*Oct.*, 1957).

(239) **Goodyear proposes smaller space station**. *Aviation Wk.*, **67** (15), 115, 117, 119 (14 *Oct.*, 1957). A report of a paper read at Barcelona to the Eighth I.A.F. Congress.

(240) **Russian satellite transmits some data**. *Aviation Wk.*, **67** (15), 27 (14 *Oct.*, 1957). News item containing description of satellite, its orbit and contents.

(241) **Satellite's glow permeates Barcelona**. D. Anderton. *Aviation Wk.*, **67** (15), 29–31 (14 *Oct.*, 1957). Opinions on launching collected at Eighth I.A.F. Congress.

(242) **Impact of Russian satellite to boost U.S. research effort**. E. Clark. *Aviation Wk.*, **67** (15), 28–9 (14 *Oct.*, 1957). Reactions to satellite launching news.

(243) **Senate group probes satellite progress**. K. Johnsen. *Aviation Wk.*, **67** (15), 31 (14 *Oct.*, 1957). One of the repercussions of the Russian satellite launching in U.S.A. Their own satellite programme scrutinized.

(244) **A new realm of flight**. *Flight*, **72**, 611–4 (18 *Oct.*, 1957). Presents data on the first Russian satellite and reactions to the news of its existence from all over the world.

(245) **Summing-up the satellite**. *Aeroplane*, **93**, 581–2 (18 *Oct.*, 1957). A description of the first satellite with an assessment of its implications.

(246) **Details of sputnik surprise scientists**. D. A. Anderton. *Aviation Wk.*, **67** (16), 30–1 (21 *Oct.*, 1957). Report of opinions from Eighth I.A.F. Congress.

(247) **Camera ready to track Soviet satellite**. *Aviation Wk.*, **67** (17), 123, 125, 127 (28 *Oct.*, 1957). Description of 20 in. dia. F.1 camera and its mounting.

(248) **Lockheed offers satellite and Moon rockets**. N. L. Baker. *Missiles and Rockets*, **2** (11), 116–8 (*Nov.*, 1957).

(249) **Sputnik is radiating strong infra-red signal**. *Aviation Wk.*, **67** (18), 31 (4 *Nov.*, 1957). Report of detection of satellite radiations.

(250) **Dog recovery viewed as feasible**. *Aviation Wk.*, **67** (19), 30 (11 *Nov.*, 1957). Speculation on recovery of *Sputnik II* contents.

(251) **Soviet shows satellite-a-month capacity**. E. Clark. *Aviation Wk.*, **67** (19), 29–30 (11 *Nov.*, 1957). Description of Russian satellite experiments and proposals.

(252) **Defense seeks cause of satellite failure**. *Aviation Wk.*, **67** (24), 28–30 (16 *Dec.*, 1957). Post mortem on Vanguard test vehicle 3, 6 Dec., 1957.

(253) **After the sputniks**. *Aeroplane*, **93**, 783–4 (22 *Nov.*, 1957). Discusses the effect of the Russian satellite launchings on scientific and military opinion.

(254) **Long range radar spots sputniks.** *Aviation Wk.*, **67** (21), 34 (25 *Nov.*, 1957). Brief description of a narrow-beam radar installation.

(255) **Red sputnik plans available last June.** E. Clark. *Aviation Wk.*, **67** (21), 30–1 (25 *Nov.*, 1957). Retrospective article on Russian release of their satellite plans.

(256) **The first satellite.** *Weltraumfahrt*, **8** (4), 101–3 (*Dec.*, 1957). (*In German.*)

(257) **The new dimension.** *Interavia*, **12** (12), 1229–33 (*Dec.*, 1957). Describes the Russian satellites, their launching rocket, their contents, and their orbits.

(258) **U.S. Army's Jupiter-C becomes satellite carrier.** *Missiles and Rockets*, **2** (12), 57, 59 (*Dec.*, 1957).

(259) **Observations on the first Earth satellites.** E. G. C. Burt. *R.A.E. News*, **10** (12), 4, 6–9 (*Dec.*, 1957).

(260) **Placing the Vanguard satellite in orbit.** J. P. Hagen. *Interavia*, **12** (12), 1245–50 (*Dec.*, 1957). A comprehensive description of the project, with diagrams of the satellite, launching rocket, and operation.

(261) **Calculations on the visibility of Earth satellites.** I. Schmidt. *Weltraumfahrt*, **8** (4), 104–7 (*Dec.*, 1957). (*In German.*) (9 *refs.*)

(262) **Problems of satellite flight.** *Flight*, **72**, 890 (6 *Dec.*, 1957). Report of a lecture by J. C. Cooper to the International Law Association, on the legal implications of the satellite launchings.

(263) **Nose cone will be army satellite.** *Aviation Wk.*, **67** (23), 77, 79 (9 *Dec.*, 1957). Brief note describes Jupiter C satellite.

(264) **Launching sputniks.** *Aeroplane*, **93**, 904 (13 *Dec.*, 1957). A descussion of, and deductions from, Russian news films of winged satellite launching vehicles.

(265) **Programs for future sputniks detailed by Russian scientists.** E. Clark. *Aviation Wk.*, **67** (24), 32–3 (16 *Dec.*, 1957). Collection of news items from Soviet news sources.

(266) **Army Jupiter satellite 30 in. long.** *Aviation Wk.*, **67** (25), 39 (23 *Dec.*, 1957). Pictures of Jupiter-C final stage.

(267) **Vanguard program moves toward TV-4 launching.** *Aviation Wk.*, **67** (26), 54–5 (30 *Dec.*, 1957). Photographs of rocket and satellite.

(268) **The Explorers.** W. von Braun. *9th Internat. Astronaut. Congr.*, 37 pp. (1958). The launching vehicles, satellites and auxillary equipment used in the U.S. Army Ballistic Missile Agency's artificial Earth satellite programme are described, and some results are given for *Explorers I-III*. To ensure that instrument temperatures inside the satellite lie within the required range, launchings from Cape Canaveral can only take place at certain times of day, but by varying the paint pattern the temperatures may be shifted by as much as 20–30° C. up or down. *Explorer V* failed because the burnt-out first stage ran into the rear of its pay-load during a coasting stage.

(269) **The lifetime of artificial satellites.** C. Casci and V. Giavotto. *9th Internat. Astronaut. Congr.*, 15 pp. (1958). (*In Italian.*) Mathematical analysis of satellite motion; deals both with a circular equatorial orbit, and with the more general case of an inclined elliptical orbit.

(270) **The photographic observation of artificial satellites.** W. J. Jaschek. *9th Internat. Astronaut. Congr.*, 4 pp. (1958). (*In German.*) Technique for photographing artificial satellites; the chief problem is that of timing. It is possible to employ commercial 35 mm. cameras.

(271) **Exploration of the upper atmosphere with the help of the third Soviet sputnik.** V. I. Krassovskii. *9th Internat. Astronaut. Congr.*, 24 pp. (1958). Instruments carried by *Sputnik III*, the problems solved with their help and the results obtained: determination of upper atmosphere densities with ionization and magnetic manometers, composition of the upper atmosphere, solar and other radiation, etc.

(272) **Techniques of analysing terrestrial radio and optical observations of Earth satellite.** R. H. Merson. *9th Internat. Astronaut. Congr.*, 14 pp. (1958). Describes the Royal Aircraft Establishment's satellite prediction service and the main features of the radio interferometer and kinetheodolite observations made by the R.A.E. staff. A method of analysing the observations on a digital computer is outlined. Orbital elements determined for *Sputnik II* are tabulated; the theoretical and observed values of the rate of rotation of the orbital plane differ by 0·7%. This indicates the possibility of improving the accepted values for the coefficients in the formula for the Earth's gravitational potential field.

(273) **The motion of an Earth satellite on re-entry to the atmosphere.** T. R. F. Nonweiler. *9th Internat. Astronaut. Congr.*, 24 pp. (1958). The equations of motion of a satellite have been solved by an approximate method relevant to that part of its re-entry where aerodynamic forces predominate. The motion is relatively insensitive to the form of orbit described beforehand, provided only that a sufficiently large number of circuits has been made. The retardation is practically independent of the size, shape and weight of the satellite; these factors merely determine the height at which retardation occurs. Frictional heating is discussed.

(274) **Preliminary summary of optical observations of artificial Earth satellites.** K. F. Ogorodnikov. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). Organization and equipment of U.S.S.R. stations for satellite observation.

(275) **Principal of inertial control of satellite attitude.** R. E. Roberson. *9th Internat. Astronaut. Congr.*, 11 pp. (1958). Attitude control of satellites or space vehicles by use of any number of internal translating and rotating parts is analysed and an expression for control torque developed. To indicate how development of the equations would proceed, two examples are considered: vibrating masses, and wheels rotating about vehicle-fixed axes.

(276) **Influence of the accuracy of the velocity vector of an artificial satellite for near-circular orbits.** K. Schütte. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). (*In German.*) The influence of the velocity vector at burn-out on the shape and location of the initial elliptic orbit of an artificial satellite has been investigated for near-circular orbits (those within 10% velocity deviation and within 5 degrees deviation of the tangent plane). Tables and graphs enabling the orbit parameters to be easily determined are given, and these also facilitate solution of the inverse problem: the determination of the required velocity vector variation in order to reach a certain goal.

(277) **Dynamic effects on the motion of Earth Sputniks.** L. I. Sedov. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). (*In English; Russian captions.*) The motion of artificial Earth satellites is discussed and the orbital elements of *Sputniks I-III* are tabulated. The measurements have been used to obtain values of the atmospheric density.

(278) **Satellite position prediction from six frequency-time pairs.** R. H. Urbano. *9th Internat. Astronaut. Congr.*, 4 pp. (1958). Deduces the equations necessary for obtaining the orbital elements of a satellite revolving about a spherical Earth from a set of six frequencies (as obtained from Doppler measurements) at six specific times. The analysis takes into account the motion of the Earth and the curvature of the satellite path.

(279) **Note on the immediate feasibility of an orbiting astronomical telescope.** F. L. Whipple. *9th Internat. Astronaut. Congr.*, 4 pp. (1958). It is possible now to place in a satellite orbit an astronomical telescope fitted with an electronic scanning device to provide an image of an area of the sky at a monitoring station on the ground.

(280) **A year's exploratory journey, Earth-Mars-Venus-Earth.** G. A. Crocco. *Astronautica*, **Pt. I. 1** (1), 3–14 (*Jan.*, 1957). **Pt. II. 1** (2), 1–11 (*April*, 1957). (*In Italian.*) Analysis of orbits and propulsion requirements. (Paper delivered at Seventh International Astronautical Congress.)

(281) **The conquest of the Moon.** E. Bergaust. *Missiles and Rockets*, **2** (3), 82–3, 85–6 (*March*, 1957). General review of lunar probe problems.

(282) **U.S.A.F. to start Moon rocket program.** E. Bergaust. *Missiles and Rockets*, **2** (3), 25–6 (*March*, 1957). Possibility of Moon rocket weighing up to 200 lb. using I.C.B.M. for launching.

(283) **Russia's Moon rocket program.** E. Bergaust. *Missiles and Rockets*, **2** (11), 37–9 (*Nov.*, 1957).

(284) **U.S. accelerates Moon plans.** *Aviation Wk.*, **67** (18), 27 (4 *Nov.*, 1957). Details of proposals for Moon probe rocket.

(285) **New Moon proposal.** *Aviation Wk.*, **67** (24), 26 (16 *Dec.*, 1957). News of a project for a 5-stage Moon probe rocket.

(286) **Recovery of a circum-lunar instrument carrier.** C. Gazley Jnr. and D. J. Masson. *9th Internat. Astronaut. Congr.*, 8 pp.

(1958). While a very high guidance capability is necessary to impact a recoverable circum-lunar vehicle within a given area on the Earth's surface, only moderate accuracy is required to effect just a return to Earth, and radio tracking would enable the approximate impact point to be predicted. Deceleration and heating would be more severe than during re-entry of a satellite, but a vaporizing surface could be used for heat absorption without an excessive weight penalty.

(287) **Considerations of the solar probe.** R. P. Haviland. *9th Internat. Astronaut. Congr.*, 8 pp. (1958). Although the present state of rocketry limits the distance of closest approach to the Sun to about the orbit of Mercury, available components would permit the design of a probe capable of reaching within 5,000,000 miles of the solar surface. Component temperatures, stabilization, telemetry and instrumentation are considered.

(288) **Efficiencies and "ramming" start of selftanking multi-coupled rockets.** J. H. Houtman. *9th Internat. Astronaut. Congr.* (1958). (*English summary.*) Proposals for the use of ram-jet boosters and lightweight jettisonable plastic propellent tanks to increase efficiency.

(289) **Astroballistics.** R. N. Thomas. *Smithsonian Contributions to Astrophysics*, **1** (1), 49–52 (1956).

(290) **Automation for interplanetary navigation.** A. L. Cardozo. *9th Internat. Astronaut. Congr.* (1958). (*English summary.*) Method and equipment for position computing and for computing the spaceship orbit and nearest approximation to the target planet.

(291) **Impulsive midcourse correction of a lunar shot.** M. W. Hunter, W. B. Klemperer and R. J. Gunkel. *9th Internat. Astronaut. Congr.*, 22 pp. (1958). An analysis of the midcourse corrections necessary to deal with any errors in trajectory of a lunar probe. Mainly concerned with the idealized two-dimensional case, but some accurate three-dimensional calculations have been made.

(292) **On the degree of accuracy to be attained by astro-scanners as an aid in automatic interplanetary course-computation.** J. J. de Kler. *9th Internat. Astronaut. Congr.* (1958). Our present knowledge is shown to be sufficient for us to design instruments of sufficient accuracy to permit interplanetary navigation with automatic course correction to reach the "practical attraction sphere" of any planet of the solar system. Mars is the most difficult target in this respect.

(293) **On the orbital computations and the guidance problem of a deep space rocket.** J. M. J. Kooy. *9th Internat. Astronaut. Congr.*, 35 pp. (1958). Mathematical treatment of the problem of guidance for a four-stage rocket, in which three stages are used to attain an elliptical satellite orbit and the final stage to transfer to a ballistic orbit sufficient to attain lunar distances or beyond. Possible control equipment is indicated.

(294) **Accuracy requirements for interplanetary ballistic trajectories.** T. A. Magness, J. B. McGuire and O. K. Smith. *9th Internat. Astronaut. Congr.*, 23 pp. (1958). Previous investigations of interplanetary trajectories have concentrated on minimum energy paths, which involve large ballistic error coefficients. The present analysis shows that error coefficients depend critically upon the choice of a nominal trajectory and may be improved by factors of ten or more. Emphasis is on Earth-Mars and Earth-Venus shots, but the methods have general application to transfer ellipses from one satellite to another in a central gravitational field.

(295) **Interplanetary trajectories with excess energy.** W. E. Moeckel. *9th Internat. Astronaut. Congr.*, 23 pp. (1958). Several families of interplanetary trajectories have been analysed in an effort to reduce total round-trip time with the least excess energy. Thus, the round trip to Venus was reduced from the least-energy value of 760 days with a total velocity increment of 8·22 miles/sec. to a round-trip time of 400 days with a total velocity increment of 9·7 miles/sec. This reduction corresponds to zero waiting time at the destination planet; a moderate increase in waiting time or further reductions in travel time necessitate considerably larger velocity increments.

7—PROPULSION

(296) **Aero-engine survey—rockets, ramjets and pressure-jets.** *Aeroplane*, **93**, 379–80 (6 *Sept.*, 1957). A brief description of power plants shown at the annual S.B.A.C. exhibition.

(297) **How N.A.C.A. views future for propulsion.** J. S. Butz. *Aviation Wk.*, **67** (16), 73–4, 80, 82–3 (21 *Oct.*, 1957). Brief general review of propulsion methods, including ionic propulsion unit.

(298) **General round-up in the ramjet field and its significance to astronautics.** G. Partel. *9th Internat. Astronaut. Congr.*, 9 pp. (1958). Reviews the various types of ramjet (chemical, nuclear, those using atmospheric atomic oxygen, and magnetic) and indicates their applications in astronautics.

(299) **Energy properties of jet propulsion.** P. Glansdorff and A. Jaumotte. *Revue Générale des Sciences Appliquées*, **3** (2), 1–12. (*In French.*)

(300) **Bibliography on jet propulsion and reaction propulsion with application to interplanetary flight. (1949–1954.)** G. Nebbia. *Bologna Tipographia Compositori*, 112 pp. (1955). (*In Italian.*)

(301) **Rocketry.** R. Tousey. *Smithsonian Contributions to Astrophysics*, **1** (1), 39–44 (1956).

(302) **"Futuristic" rockets will soon provide economical energy.** J. A. Browning. *Welding Engineer*, **41**, 30–2 (*Jan.*, 1956). Commercial applications.

(303) **Fluorocarbons and rocket cases for missiles.** F. J. Horn and R. D. Miller. *Jet Propulsion*, **26** (10, Pt. 2), 17S (*Oct.*, 1956). Products of M. W. Kellogg Co.

(304) **Rocketry and related fields.** W. H. Winnard. *Jet Propulsion*, **26**, (10, Pt. 2), 2S–3S (*Oct.*, 1956). Some of Aerojet-General Corp's products and services.

(305) **Aerojet-General's Sacramento test facility.** *American Rocket News*, **1** (2), 10–11 (*March*, 1957). Photos.

(306) **Rocket propulsion units.** Vernet-Lozet. *Interavia*, **12** (8), 799–801 (*Aug.*, 1957). A general review of the characteristics of liquid and solid rocket motors.

(307) **Britain's aircraft and aero-engines—rocket engines.** *Aeroplane*, **93**, 321 (30 *Aug.*, 1957). A data sheet on these engines.

(308) **Power unlimited.** *Missiles and Rockets*, **2** (9), 128–9 (*Sept.*, 1957). Photos of large rocket test stands.

(309) **Contribution of thermodynamics to the evaluation of rocket possibilities or performances.** M. Serruys. *9th Internat. Astronaut. Congr.*, 20 pp. (1958). (*In French.*) Importance of exhaust velocity; calculation of exhaust velocity; specific impulse evaluation of performance of multistage rockets.

(310) **The applicability of solid propellant to high performance rocket vehicles.** M. Summerfield, J. I. Shafer, H. L. Tackwell and C. E. Bartley. *Calif. Inst. Tech., Jet Prop. Lab. Memo*, 4–17, 41 pp. (*Oct.*, 1947).

(311) **Solid fuel industry round-up.** *Missiles and Rockets* **2** (8), 67–73 (*Aug.*, 1957). Review of interested private firms and government agencies. Summary of propellent types, performances and hardware.

(312) **Thiokol geared for solid propellant business boom.** N. L. Baker. *Missiles and Rockets*, **2** (8), 121–2 (*Aug.*, 1957). Present activities and capabilities.

(313) **Machining for solid propellent rockets.** J. H. Kauffmann. *Missiles and Rockets*, **2** (8), 105–8, 110–1 (*Aug.*, 1957).

(314) **Small solid rockets for commercial use.** G. E. Rice. *Missiles and Rockets*, **2** (8), 80–1 (*Aug.*, 1957). Assisted take-off and emergency use.

(315) **Solid propellant rocket testing.** H. E. Westgate. *Missiles and Rockets*, **2** (8), 87–90 (*Aug.*, 1957). General test procedure.

(316) **Solid propellant bibliography.** A. J. Zaehringer. *Jet Propulsion*, **27**, 900–27 (*Aug.*, 1957).

(317) **Thermal stresses in an infinite, hollow case-bonded cylinder.** S. A. Zwick. *Jet Propulsion*, **27**, 872–6 (*Aug.*, 1957). Application to solid propellent grains. (3 *refs.*)

(318) **Solid fuels contend for long range ballistic role**. J. S. Butz. *Aviation Wk.*, **67** (14), 50–2, 54, 57, 59 (7 *Oct.*, 1957). Comparison of solid and liquid fuel motor installations for large rockets.

(319) **On solid propellent rockets**. E. Mohr. *Weltraumfahrt*, **8** (4), 111–6 (*Dec.*, 1957). (*In German.*)

(320) **Note on the optimum design of solid propellent power-plants for missiles systems engineering**. J. A. Vandenkerckhove. *9th Internat. Astronaut. Congr.*, 14 pp. (1958). Method for determining the geometry/chamber pressure combination which gives the optimum design for a solid propellent rocket of specified thrust and burning time. Indicates the advantage in using several motors instead of a single unit where large thrusts and burning times are concerned. The acceleration of a rocket up to a given speed is also studied.

(321) **Film cooling**. R. H. Boden. *Calif. Inst. Tech., Jet Prop. Lab. Tech. Progr. Rept.* 4–19, 54 pp. (*Jan.*, 1946).

(322) **Design, performance and servicing of WAC Corporal propulsion systems**. P. J. Meeks and R. C. Terbeck. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–20, 72 pp. (*April*, 1946).

(323) **Optimal volume of gas container for the propulsion of liquid propelled rockets**. P. Larue. *Off. Nat. Études Rech. Aéronaut., Note Techn.* **54**, 17–20 (*Nov.-Dec.*, 1956). (*In French.*)

(324) **Experimental study of nitromethane rocket motors with varying fineness ratio, characteristic length and chamber pressure**. C. R. Foster. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–33, 25 pp. (*May*, 1947).

(325) **Performance tests of the 220 lb. thrust Lark motor**. A. Briglio. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–39, 37 pp. (*Aug.*, 1947).

(326) **Wall temperature in regeneratively cooled rocket motors**. J. Lorell. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 4–29, 16 pp. (*Feb.*, 1948).

(327) **Effect of method of pumping propellant on weight and performance of rocket propelled vehicles**. J. B. Kendrick. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–43, 31 pp. (*Aug.*, 1948).

(328) **Effect of spin on rocket motor performance**. R. H. Boden. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–49, 12 pp. (*April*, 1949).

(329) **A preliminary design study of a 2600 lb. thrust liquid propellant rocket motor**. R. B. Canright. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–23, 47 pp. (*June*, 1956).

(330) **Controlled explosive power units**. F. W. La Haye. *Jet Propulsion*, **26**, (10, Pt. 2), 14S–16S (*Oct.*, 1956). Gas generators, igniters and explosive bolts manufactured by McCormick Selph Associates.

(331) **Development of control, fuel cut-off. C 1297 (XE-1/DPN)**. G. L. Zomber. *Avion Div., American Car & Foundry Co. Report* 849. 94 pp. (*Dec.*, 1956). (*Available as PB* 134,278.) Control developed as missile component to provide for permanent closing of a switch upon receipt of a preselected audio signal.

(332) **The rocket motor SEPR 481**. *Weltraumfahrt*, **8** (1), 6–8 (*Feb.*, 1957). (*In German.*)

(333) **Thrust chamber fabrication**. *Amer. Rocket News*, **1** (1), 14 (*Feb.*, 1957).

(334) **Combustion instability in liquid propellant rocket motors. Nineteenth quarterly progress report for the period 1 November, 1956–31 January 1957**. *Princeton Univ., Dept. Aeronaut. Engng. Rept.* 216–S, 25 pp. (*March*, 1957).

(335) **Injector design**. *American Rocket News*, **1** (2), 14, 41 (*March*, 1957). General review of designs and manufacturing techniques.

(336) **Rocket engines for outer space**. R. C. Truax. *American Rocket News*, **1** (2), 8, 27, 41 (*March*, 1957). Effect of zero ambient pressure on engine design. To reduce weight, chamber pressure could be reduced perhaps to 2 atmospheres but possibility of bulk-boiling of coolant in jacket must be watched. Starting may also present problems in zero-pressure, zero-gravity conditions.

(337) **Cylindrical rocket combustion chambers**. H. von Zborowski. *Raktech. u. Raumforsch.*, (1), 1–3 (*April*, 1957); *Weltraumahrt*, **8** (2), 41–4 (*May*, 1957). (*In German.*) Descriptive review of chamber shapes.

(338) **Digital computer analysis of transients in liquid rocket engines**. P. Kluger and E. C. Farrel. *Jet Propulsion*, **28** (12), 804–809 (*Dec.*, 1958). Method for evaluating pressure surges in the propellent system during startup and shutdown, using a mathematical model based on Allievi's water-hammer theory.

(339) **On generalized scaling procedures for liquid-fuel rocket engines**. S. S. Penner and A. E. Fuhs. *Combustion and Flame*, **1**, 229–40 (*June*, 1957).

(340) **Gas-side wall temperatures in rib-backed liquid-cooled combustion chambers**. J. G. Bartas. *Jet Propulsion*, **27** (7), 784–6 (*July*, 1957). An analysis of the temperature profile along the axis of symmetry of the rib, and a design chart, are reported.

(341) **Rocket power-plants of the Société d'Étude de la Propulsion par Réaction (S.E.P.R.)**. H. Schneider. *Flugwelt*, **9**, 522–4 (*July*, 1957). (*In German.*) Outline of activities of the company and tabulated data of their power plants.

(342) **Development of apparatus for warming hydrogen peroxide by its own controlled decomposition**. J. G. Tschinkel and A. E. Graves. *Jet Propulsion*, **27** (7), 796–8 (*July*, 1957). Describes the apparatus and its operation.

(343) **Temperatures and thermal stresses in transpiration-cooled power-producing plates and tubes**. P. J. Schneider. *Jet Propulsion*, **27**, 882–9 (*Aug.*, 1957). (10 *refs.*)

(344) **A mechanical igniter for liquid rocket engines**. K. R. Stehling and J. L. Freeland. *Jet Propulsion*, **27**, 896–7 (*Aug.*, 1957).

(345) **Investigation of the factors affecting the attachment of a liquid film to a solid surface**. C. F. Warner and B. A. Reese. *Jet Propulsion*, **27**, 877–81 (*Aug.*, 1957). Relates to film cooling. (15 *refs.*)

(346) **Genesis of the Spectre**. *Aeroplane*, **93**, 248–9 (23 *Aug.*, 1957). Description of this De Havilland rocket engine.

(347) **Spectre**. *Flight*, **72**, 245 (23 *Aug.*, 1957). Details of the De Havilland rocket motor inferred from its external appearance.

(348) **S.E.P.R. rockets power French fighters**. D. A. Anderton. *Aviation Wk.*, **67** (8), 66–8, 73–4 (26 *Aug.*, 1957). Review of French rocket motors for aircraft and missiles.

(349) **Effect of fluid-system parameters on starting flow in a liquid rocket**. R. P. Krebs. *N.A.C.A. Tech. Note* 4034, 38 pp. (*Sept.*, 1957).

(350) **Liquid rocket engine control**. R. H. Reichel. *Missiles and Rockets*, **2** (9), 101–2, 104, 106 (*Sept.*, 1957).

(351) **Spectre: first throttleable production rocket**. J. H. Stevens. *Missiles and Rockets*, **2** (9), 48–9 (*Sept.*, 1957).

(352) **Propulsion systems evaluated**. G. P. Sutton. *Missiles and Rockets*, **2** (9), 123–4, 126 (*Sept.*, 1957).

(353) **Safety, long life claimed for Spectre**. *Aviation Wk.*, **67** (9), 65 (2 *Sept.*, 1957). Illustrated press release on this De Havilland rocket engine.

(354) **Spectre fired for test on mockup of SR53 rocket-jet fighter**. *Aviation Wk.*, **67** (10), 71–2 (9 *Sept.*, 1957). Pictures of static firing.

(355) **Combustion instability in solid propellent rocket motors**. E. W. Price. *9th Internat. Astronaut. Congr.*, 9 pp. (1958). The phenomena occurring during combustion instability are described and methods for its detection are indicated. There is considerable controversy concerning the actual mechanism. There are three methods of suppression: acoustic interference (the geometry is chosen so that no natural modes of the combustion chamber cavity are easily excited), damping (action of "resonance rods" or of solid or liquid particles in the gas flow: the particles do not oscillate with the same amplitude as the gas and the relative velocity leads to both viscous and thermal damping), and excitation blocking (making the combustion unresponsive to gas flow oscillations). Additives to the propellent may act by either or both of the last two mechanisms. Some promising work has been done with additives such as carbon, aluminium and aluminium oxide.

(356) **Contoured rocket nozzles**. G. V. R. Rao. *9th Internat. Astronaut. Congr.*, 23 pp. (1958). Presents a method of designing rocket nozzle wall contours to yield optimum thrust, assuming isentropic, adiabatic, frictionless gas flow. A typical numerical example is given, for a LOX and JP-4 propellent combination. The low-altitude performance of such a contoured nozzle is discussed.

(357) **The output factor, characteristic of the quality of the combustion in a rocket engine.** W. Zangl. *9th Internat. Astronaut. Congr.*, 9 pp. (1958). (*In French.*) Indicates the dependence of the propellent consumption efficiency on various influences.

(358) **A study of ignition lag characteristics of some liquid rocket fuels with red fuming nitric acid, including additives to the oxidizer.** B. R. Adelman. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 20–138, 14 pp. (*April*, 1941).

(359) **A survey of three propellent combinations—ethyl alcohol, methyl alcohol and gasoline with liquid oxygen.** J. F. Tormey. *North American Aviation Rept. AL*107, 29 pp. (*Feb.*, 1947).

(360) **Studies of the rocket motor propellant combinations: hydrogen peroxide—nitromethane and hydrogen peroxide—methyl alcohol.** C. R. Foster. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 1–64, 28 pp. (*Aug.*, 1947).

(361) **An investigation of the white fuming nitric acid-furfuryl alcohol rocket propellant.** R. H. Boden and A. Briglio. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 4–67, 31 pp. (*May*, 1948).

(362) **The nitrogen oxides as rocket fuel oxidants including the theoretical performances of propellant systems employing nitrogen tetroxide.** L. G. Cole. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 9–23, 42 pp. (*Oct.*, 1948).

(363) **The effect of gaseous atmospheres on the burning rate of solid propellants.** J. L. Jones, R. T. Moore and J. K. Holcomb. *Calif. Inst. Tech., Jet Prop. Lab., Progr. Rept.* 9–44, 30 pp. (*Oct.*, 1949).

(364) **Apparatus for laboratory scale determination of ignition lag of spontaneous liquid rocket propellants.** B. R. Adelman. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 9–52, 10 pp. (*Feb.*, 1951).

(365) **A study of the use of starting fuels for ignition of red fuming nitric acid—JP3.** D. D. Thomas. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 1–77, 9 pp. (*Sept.*, 1951).

(366) **Ignition lag characteristics of some hydrazine nitric acid propellant systems.** B. R. Adelman. *Calif. Inst. Tech., Jet Prop. Lab., Progr. Rept.* 20–164, 10 pp. (*Jan.*, 1952).

(367) **The combustion of atomized liquid propellants.** C. C. Miesse. *Aerojet-General Corp.*, 30 pp. (1956). Review of literature.

(368) **Experimental investigation of liquid diborane—liquid oxygen propellant combination in 100 pound thrust rocket engine.** W. H. Rowe, P. M. Ordin and J. M. Diehl. *N.A.C.A. Res. Memo, E55J*31, 12 pp. (*Feb.*, 1956).

(369) **Theoretical performance of JP-4 fuel and liquid oxygen as a rocket propellant. I. Frozen composition.** V. N. Huff and A. Fortini. *N.A.C.A. Res. Memo. E56A*27, 35 pp. (*April*, 1956).

(370) **A preliminary investigation of neoprene-potassium perchlorate restricted solid propellants.** C. E. Bartley. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 4–25, 34 pp. (*Aug.*, 1946).

(371) **Theoretical performance of JP-4 fuel and liquid oxygen as a rocket propellant. II. Equilibrium composition.** V. N. Huff and A. Fortini. *N.A.C.A. Res. Memo. E56D*23, 47 pp. (*Sept.*, 1956).

(372) **Some possibilities of using hot water for the propulsion of rockets.** P. Duban. *Off. Nat. Études Rech. Aéronaut., Note Techn.* 54, 9–16 (*Nov.-Dec.*, 1956). (*In French.*)

(373) **Factors which influence the suitability of liquid propellants as rocket motor regenerative coolants.** D. R. Bartz. *Calif. Inst. Tech., Jet. Prop. Lab. Memo.* 20–139, 24 pp. (*Dec.*, 1956). (*Available* as *PB*133,818.)

(374) **Investigations on some properties of certain hypergols.** J. Françon. *Publ. Sci. Min. Air Note Techn.* 66, 46 pp. (1957). (*In French.*)

(375) **The decomposition burning of monopropellant drops: hydrazine, nitromethane and ethyl nitrate.** W. A. Rosser. *Calif. Inst. Tech., Jet. Prop. Lab. Progr. Rept.* 20–305, 12 pp. (*Jan.*, 1957).

(376) **Method for determining the tensile properties of solid rocket propellants. Part II—Composite propellants.** *Solid Propellant Information Agency SPIA/PP*8, 16 pp. (*Feb.*, 1957).

(377) **"Yellow powder" propellent.** G. von Francois. *Weltraumfahrt*, **8** (1), 13–14 (*Feb.*, 1957). (*In German.*) Description, with performance data, of solid propellent based on tetranitrocarbazol and potassium nitrate.

(378) **Fluorine propellant study. Quarterly progress report for period ending Feb. 1957.** *North American Aviation, Rocketdyne Div. Rept. R*-334-3, 12 pp. (*March*, 1957).

(379) **Thermodynamic and performance data for liquid propellents for rocket motors.** E. Büchner. *Raktech. u. Raumforsch.*, (1) 4–10 (*April*, 1957). (*In German.*) Theoretical and practical data for a wide variety of propellent mixtures. (3 *refs.*)

(380) **The effect of chemical structure on the hypergolic ignition of amine fuels.** L. R. Rapp and M. P. Strier. *Jet Propulsion*, **27**, 401–4 (*April*, 1957). Apparatus and results.

(381) **Potential applications of radioisotopes to process and quality control in the manufacture of propellants and explosives.** S. Helf, T. C. Castorini and F. S. Holahan. *Picatinny Arsenal Report PATR* 2435, 20 pp. (*May*, 1957). (*Available as PB*132,952.)

(382) **Hydrogen peroxide or nitric acid?** H. Schneider. *Weltraumfahrt*, **8** (2), 63–7 (*May*, 1957). (*In German.*) Comparison as oxidants for rocket motors with emphasis on handling and safety.

(383) **Estimation of optimum mixture ratio for fuming nitric acid propellants.** J. S. Gordon. *Jet Propulsion*, **27** (7), 799 (*July*, 1957). Proposes a new mixture ratio formula to replace that given by the "J. P. L. Short Method" of performance estimation. (1 *ref.*)

(384) **Ethylene oxide as a monopropellant.** S. A. Greene and L. J. Gordon. *Jet Propulsion*, **27** (7), 798–9 (*July*, 1957). Describes the properties and decomposition products of ethylene oxide. (8 *refs.*)

(385) **Oxidants for aircraft rocket motors.** *Weltraumfahrt*, **8** (3), 74–6 (*Aug.*, 1957). (*In German.*)

(386) **Solid propellant rocketry.** J. K. Elder. *Interavia*, **12** (8), 801–2 (*Aug.*, 1957). Gives an account of the different types of solid propellent and their applications.

(387) **Swing to solid propellants.** J. Wilson. *Missiles and Rockets*, **2** (8), 92–4 (*Aug.*, 1957). Solid versus liquid discussion.

(388) **Propellants for tomorrow's rockets.** F. Zwicky. *Astronautics*, **2** (1), 45–9, 95–7 (*Aug.*, 1957). Conventional chemicals of high performance, free radicals and methods of using atomic energy.

(389) **1957 liquid propellant round-up.** *Missiles and Rockets* **2** (9), 82–6 (*Sept.*, 1957).

(390) **Boron plays lead role in H.E.F. development.** N. L. Baker. *Missiles and Rockets*, **2** (9), 157–8, 161–2 (*Sept.*, 1957).

(391) **Liquid propellants for manned rocket aircraft.** W. Mitchell, *Missiles and Rockets*, **2** (9), 109–10, 112, 114 (*Sept.*, 1957).

(392) **Aircraft rocket engine oxidants.** W. N. Neat. *Interavia*, **12** (9), 929–30 (*Sept.*, 1957). An account of the factors influencing the choice of an oxidant, compares liquid oxygen, nitric acid, and hydrogen peroxide.

(393) **Fluorine—tamed for rockets.** H. R. Neumark and F. L. Holloway. *Missiles and Rockets*, **2** (9), 97, 99–100 (*Sept.*, 1957).

(394) **Dimazine—comes of age as rocket fuel.** W. G. Strunk. *Missiles and Rockets*, **2** (9), 116–8, 120 (*Sept.*, 1957).

(395) **Lox—mainstay oxidizer for the missile age.** W. H. Thomas. *Missiles and Rockets*, **2** (9), 131–2 (*Sept.*, 1957).

(396) **What's all this talk about exotic propellants?** J. F. Tormey. *Missiles and Rockets*, **2** (9), 93–4 (*Sept.*, 1957).

(397) **Heat problems limit rocket fuel gains.** *Aviation Wk.*, **67** (9), 33 (2 *Sept.*, 1957). Report of A.R.S. paper on high-energy propellents.

(398) **Borane high energy fuels.** *Interavia*, **12** (12), 1023 (*Oct.*, 1957). The boranes compared with more conventional fuels.

(399) **A contribution to the theme H_2O_2 versus HNO_3.** E. Kruska. *Weltraumfahrt*, **8** (4), 109–10 (*Dec.*, 1957). (*In German.*)

(400) **Solid fuels may claim big-missile field.** R. Hawkes. *Aviation Wk.*, **67** (25), 37–41 (23 *Dec.*, 1957). Discussion of some of the advantages of solid fuels for large rockets.

(401) **Liquid and solid propellents for rockets.** E. Büchner. *9th Internat. Astronaut. Congr.*, 7 pp. (1958). (*In German.*) Performance data for various combinations of fuel and oxidant.

(402) **Theoretical study of the combustion of ergol droplets in a rocket combustion chamber.** J. Corbeau and C. Diol. *9th Internat. Astronaut. Congr.*, 32 pp. (1958). (*In French.*) Factors

studied included rate of injection, turbulence, degree of atomization and chamber dimensions.

(403) **Fissiothermic autopropulsion units: radiative processes of heat transfer permitting the acceleration of mass particles.** J. J. Barré. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). (*In French.*) Preliminary calculations for fission-type nuclear rockets; suspension of carbon particles in the working fluid to produce black body conditions.

(404) **Working fluids for rockets not heated conventionally.** I. Sänger-Bredt. *9th Internat. Astronaut. Congr.*, 20 pp. (1958). (*In German.*) After reviewing the possible types of rocket, computed values of the thermodynamic properties of some hydrogen/oxygen working fluid mixtures are given for temperatures up to 10,000° K. Hydrogen-rich fluids are best where electric or magnetic fluids fields are not employed; but where a high degree of ionization is required (as in ion rockets), the alkali metals or their compounds offer advantages.

(405) **The attainment of exhaust velocities up to 20,000 metres/sec. by means of isothermal expansion in nuclear rockets.** F. Winterberg. *9th Internat. Astronaut. Congr.*, 19 pp. (1958). (*In German.*) Thermodynamics of a rocket engine in which the working medium is heated in a nuclear reactor and then allowed to expand in a Laval nozzle.

(406) **Performance limits of ion propulsion spaceships employing the energy of fission of uranium nuclei or of fusion of deuterium nuclei.** E. Ostinelli. *9th Internat. Astronaut. Congr.*, 12 pp. (1958). (*In Italian.*) The optimum theoretical exhaust velocities for the fission and fusion rockets have been calculated as 5400 and 19,500 miles/sec. respectively.

(407) **Electric propulsion systems in space flight.** L. R. Shepherd. *9th Internat. Astronaut. Congr.*, 16 pp. (1958). Looking beyond the conventional chemical rockets and the nuclear-thermal rockets now being developed, electrical propulsion systems (ion rockets) can be envisaged. Possible forms of generator and accelerator are considered; the most suitable system would appear to be a closed cycle plasma generator coupled to a magnetic plasma accelerator.

(408) **Some interesting reactions of dissociated elements.** L. Boni. *Astronautica*, **5** (2), 32–5 (*April*, 1957). (*In Italian.*) Use of free radicals for propulsion.

(409) **Putting free radical propulsion into rocket offers big challenge.** *Aviation Wk.*, **67** (24), 55, 57 (16 *Dec.*, 1957). American Rocket Society meeting report.

(410) **Free-radical power must await research.** *Aviation Wk.*, **67** (25), 51, 53 (23 *Dec.*, 1957). Counterblast to earlier optimism on development of such fuels.

(411) **Plasma motors: the propulsion of plasma by magnetic means.** W. H. Bostick. *9th Internat. Astronaut. Congr.*, 30 pp. (1958). Mathematical examination of four types of motor which might be used to propel plasmas by magnetic means; experiments are in progress. It should be easily possible to produce velocities of 2×10^7 cm./sec., corresponding to a specific impuse of 2×10^4 sec. It would be feasible to use the plasma motor as a power transformer with a variable ratio so that the exhaust velocity can be maintained at the optimum value.

(412) **Electric power for space flight.** J. H. Huth. *9th Internat. Astronaut. Congr.*, 8 pp. (1958). Power requirements for scientific satellites should not exceed 100 watts and may be provided by various types of electrochemical cells, solar cells or possible radioisotope units. Electrically-propelled manned space vehicles would require several megawatts; possibilities of supplying this demand by nuclear reactors or solar energy devices are discussed.

(413) **Application of electric-arc plasma generators to propulsion.** R. John, W. Bade, R. Schweiger, J. Yos and M. E. Malin. *9th Internat. Astronaut. Congr.*, 23 pp. (1958). Presents information obtained in the laboratories of Avco Manufacturing Corporation on the performance of high-power (25–500 kW.) fluid-stabilized electric arcs, and on techniques for the measurement of plasma properties. Estimates are presented of plasma generator specific impulse and thrust, and comparisons made with other propulsion systems.

(414) **Space propulsion by interstellar gas.** B. Karlovitz and B. Lewis. *9th Internat. Astronaut. Congr.*, 4 pp. (1958). The system here described is based on the principle of the Karlovitz-Halasz generator and involves the ionization of interstellar gas ahead of the space vehicle followed by acceleration of the ionized gas mass by the electromagnetic field system of the ship.

(415) **Use of atomic hydrogen as a propellent for liquid rockets.** W. Peschka. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). (*In German.*) Problems in the production of atomic hydrogen and its use as a rocket propellent. Possibility of using helium.

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8—MISSILES

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(419) **A study of the influence of specific impulse and density on the performance of rocket vehicles.** R. V. Meghreblian. *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 1–31, 55 pp. (*Dec.*, 1950).

(420) **The oil-spray rocket for rescues at sea.** J. Schumacher and H. Langkrär. *Raketenbrief*, **5** (1), 3–6 (*Jan.-Feb.*, 1957). (*In German.*) Description of a rocket designed to spray oil on rough seas to enable rescues to be made.

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(423) **First annual guided missile encyclopedia.** *Missiles and Rockets*, **2** (7), 123–64 (*July*, 1957). Full descriptions with data and photos of Nike Ajax, Hawk, Nike Hercules, Dart, La Crosse, Little John, Honest John, Corporal, Sergeant, Redstone, Jupiter, Bullpup, Corvus, Diamondback, Sidewinder, Zuni, Sparrow, various torpedoes, Terrier-Tartar, Regulus I, Talos, Triton, Regulus II, Polaris, Mighty Mouse, Falcon, Bomarc, Rascal, Matador, Snark, Navaho, Thor, Atlas and Titan. Brief data on Ding-Dong, Green Quail, Duck, Goose, WS-126A and WS-132A.

(424) **Open market for guided missiles.** *Interavia*, **12** (7), 697–8 (*July*, 1957). Pictures of exhibits at the Paris Air Show, 1957.

(425) **Colomb-Bechar, the French Woomera.** R. de Narbonne. *Aeroplane*, **93**, 53–4 (12 *July*, 1957).

(426) **The West's guided missiles.** *Interavia*, **12** (8), 795–8 (*Aug.*, 1957). Silhouettes to scale and tabulated data on the missiles in production and under development.

(427) **The rocket comes of age.** W. von Braun. *Interavia*, **12** (8), 789–90 (*Aug.*, 1957). The uses of the rocket in modern warfare and peace.

(428) **Missiles at the Paris show.** M. M. Decker. *Interavia*, **12** (8), 792–4 (*Aug.*, 1957). Data on the guided missiles shown at Paris and a discussion of their military importance.

(429) **Some observations on guided missiles**. T. von Karman. *Interavia*, **12** (8), 777–8 (*Aug.*, 1957). A brief review of the problems of reliability, aerodynamics, and kinetic heating in missile research.

(430) **Solid fuel missiles for the Army**. J. I. Shafer. *Missiles and Rockets*, **2** (8), 84–5 (*Aug.*, 1957). Review of requirements.

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(434) **British missiles 1957**. *Flight*, **72**, 328–30, 371 (30 *Aug.*, 1957). A review of the material released on British guided weapons.

(435) **Background to Britain's guided weapons**. J. R. Cownie. *Aeroplane*, **93**, 275–8 (30 *Aug.*, 1957). A general review of British guided missiles and their development.

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(437) **The 18th S.B.A.C. display, guided weapons**. *Flight*, **72**, 379 (6 *Sept.*, 1957). Short notes on the guided weapons exhibited at the Farnborough S.B.A.C. Show.

(438) **S.B.A.C. display suggests British missile policy is premature**. D. A. Anderton. *Aviation Wk.*, **67** (10), 26–31 (9 *Sept.*, 1957). Report of Farnborough air show, descriptions of missiles in static display included.

(439) **Guided weapons equipment on show**. *Aeroplane*, **93**, 413–6 (13 *Sept.*, 1957). Report of detailed examination of the missiles at the S.B.A.C. exhibition at Farnborough.

(440) **On the ground—guided weapons**. *Flight*, **72**, 444–9 (13 *Sept.*, 1957). Account of the exhibits at the S.B.A.C. show.

(441) **Missiles at Farnborough show British trends**. *Aviation Wk.*, **67** (11), 32–3 (16 *Sept.*, 1957). Illustrations.

(442) **Saengers describe Soviet missiles**. *Aviation Wk.*, **67** (11), 73 (16 *Sept.*, 1957). Report of information collected in Germany.

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(444) **Report on missiles and rockets around the globe**. *Missiles and Rockets*, **2** (10), 71–86, 89–91, 93–5, 97–9, 101, 104–5 (*Oct.*, 1957). Missiles from Russia, Canada, Australia, Great Britain, Switzerland, France, Sweden, Japan and Italy.

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(446) **Missiles**. G. Cattaneo. *Alata*, **13** (148), 17–21, 23–5 (*Oct.*, 1957). (*In Italian.*) Farnborough review.

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(450) **Guided missiles at Cranfield**. *Aeroplane*, **93**, 625–6 (25 *Oct.*, 1957). Describes one of the N.A.T.O. courses on guided missiles held at the College of Aeronautics.

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(452) **Single manager to head anti-missile push**. C. Witze. *Aviation Wk.*, **67** (21), 26–7 (25 *Nov.*, 1957). Report of organisational changes in counter-missile research and development in the U.S.

(453) **Guided weapons and aircraft**. *Aeroplane*, **93**, 805–6 (29 *Nov.*, 1957). A report of the inaugural lecture given to the Guided Flight Section of the R.Ae.S.

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(455) **Red Square rocket parade**. *Interavia*, **12** (12), 1244 (*Dec.*, 1957). Pictures of Russian missiles.

(456) **Minuteman to missileman**. G. T. Cahill. *Missiles and Rockets*, **2** (12), 77–8 (*Dec.*, 1957).

(457) **Soviet troops get new missiles**. F. G. McGuire. *Missiles and Rockets*, **2** (12), 37, 39 (*Dec.*, 1957).

(458) **Training potentialites of synthetic missiles**. J. G. Vaeth and J. Huson. *Missiles and Rockets*, **2** (12), 119–20 (*Dec.*, 1957).

(459) **Missiles 1957**. *Flight*, **72**, 869–79, 893–906 (6 *Dec.*, 1957). "Flight" annual review of the world's guided weapons.

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(461) **Scientists explain U.S. technical lag**. *Aviation Wk.*, **67** (26), 73, 77–82 (30 *Dec.*, 1957). Report of investigations of Senate subcommittee into slowness of rocket and satellite programmes.

(462) **Terrier data processing**. *American Rocket News*, **1** (2), 32, 34 (*March*, 1957). Use of the Milli S.A.D.I.C. equipment.

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(466) **Fireflash**. *Flight*, **72**, 223–7 (16 *Aug.*, 1957). Fairey's air-to-air guided weapon described and illustrated.

(467) **Presenting the Fireflash**. *Aeroplane*, **93**, 218–21 (16 *Aug.*, 1957). Describes the weapon in detail, and its development by the Fairey Aviation Co.

(468) **Fireflash follow-up**. *Flight*, **72**, 251 (23 *Aug.*, 1957). Data additional to those given on pages 223–7 (16 *Aug.*, 1957).

(469) **Guidance, production details show simplicity of Fireflash**. J. Tunstall. *Aviation Wk.*, **67** (8), 79–80, 83, 85 (26 *Aug.*, 1957). Missile and its boost motors described.

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(471) **Manhour investment high on Sparrow I**. *Aviation Wk.*, **67** (12), 104–5, 109, 107 (16 *Sept.*, 1957). Description of beam-riding air-to-air missile.

(472) **French Matra R.510 air-to-air missile**. *Aviation Wk.*, **67** (19), 61 (11 *Nov.*, 1957). Illustration.

(473) **Firestreak groomed for operational use**. D. A. Anderton. *Aviation Wk.*, **67** (22), 68–9, 71–3 (2 *Dec.*, 1957). Descriptions of British air-to-air missile, its aircraft installations and development.

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constant thrust, constant specific impulse, constant g and zero drag for each stage. (2 *refs.*)

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(482) **America's surface-to-surface missile arsenal.** F. I. Ordway and R. C. Wakeford. *Spaceflight*, **1**, 176–85 (*Oct.*, 1957).

(483) **Army missiles unit assembles Redstone.** *Aviation Wk.*, **67** (15), 129 (14 *Oct.*, 1957). A page of pictures.

(484) **Funds preclude I.C.B.M. defense for cities.** *Aviation Wk.*, **67** (15), 37 (14 *Oct.*, 1957). Anti-missile progress and policy described.

(485) **How U.S. taps Soviet missile secrets.** *Aviation Wk.*, **67** (16), 26–7 (21 *Oct.*, 1957). Uses of radar equipment installed in Turkey to watch I.C.B.M. trials.

(486) **Performance of long range hypervelocity vehicles.** A. J. Eggers. *Jet Propulsion*, **27**, 1147–51 (*Nov.*, 1957). (5 *refs.*)

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(492) **Static facility complex prepares ballistic missiles for launching.** *Aviation Wk.*, **67** (23), 50–1 (9 *Dec.*, 1957). Illustrations of various large-scale test facilities.

(493) **Russians study I.C.B.M. deception by fragmentation of final stage.** *Aviation Wk.*, **67** (25), 24 (23 *Dec.*, 1957). Thoughts on a counter-countermissile technique.

(494) **Solid propellant booster rocket gives Regulus II 115,000 lb. push.** *Aviation Wk.*, **67** (25), 44–5 (23 *Dec.*, 1957). Photographs of launching.

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(499) **The spectacular X-17.** *Missiles and Rockets*, **2** (4), 114–5 (*April*, 1957). Photos.

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(501) **Far Side: bargain counter space exploration.** *Missiles and Rockets*, **2** (8), 45, 47–8 (*Aug.*, 1957). Proposed programme.

(502) **Japanese Kappa 3 reaches 2420 m.p.h.** *Aviation Wk.*, **67** (7), 68 (19 *Aug.*, 1957). Report of early firings of two-stage upper atmosphere rocket.

(503) **Some problems of instrumentation and telemetry in Skylark.** A. W. Lines. *R.A.E. News*, **10** (9), 29–30, 33–4, 36 (*Sept.*, 1957).

(504) **The I.G.Y. research rocket problem.** *I.G.Y. Bulletin*, (4), 4–7 (*Oct.*, 1957).

(505) **Project Far Side.** S. F. Singer. *Missiles and Rockets*, **2** (10), 120–2, 124–8 (*Oct.*, 1957).

(506) **Farside hits 4000 mile altitude.** *Aviation Wk.*, **67** (17), 31 (28 *Oct.*, 1957). News item on first six firings.

(507) **Russian Meteo rocket firing.** *Aviation Wk.*, **67** (17), 67 (28 *Oct.*, 1957). Photographs of upper atmosphere rocket and instrument container.

(508) **Farside assembled for 4000 mile flight.** *Aviation Wk.*, **67** (19), 96–7 (11 *Nov.*, 1957). Illustrations of rocket and firing.

(509) **Oriole—a really low-cost research missile.** *Missiles and Rockets*, **2** (12), 86–7 (*Dec.*, 1957).

(510) **Project Farside.** *Interavia*, **12** (12), 1249 (*Dec.*, 1957). Pictures of the balloon and handling equipment.

(511) **Rockets for research.** *Flight*, **72**, 886–8 (6 *Dec.*, 1957). Comparison of U.S. and other high altitude rockets, with their uses and performances.

(512) **Kappa rocket.** H. Itokawa. *9th Internat. Astronaut. Congr.* (1958). The Institute of Industrial Science of the University of Tokyo began work on rockets in April, 1955, in order to develop an upper atmosphere sounding rocket for the I.G.Y. Two small solid-propellent rockets (Pencil and Baby) were used for the initial studies, then in 1956 single-stage Kappa rockets were fired. Two-stage vehicles (Kappas 3 and 4) were tested in 1957. In 1958 an altitude of 70 km. was reached with Kappa type 6. The maximum speed attained was Mach 5·5. A Kappa type 7 is being developed with the aim of reaching 100 km. altitude.

(513) **Optimum trajectories of rockets.** B. Fraeijs de Veubeke. *Revue Générale des Sciences Appliquées*, **3** (2), 13–26 (1956). (*In French.*)

(514) **Optical tracking instruments.** T. P. Fahy. *Jet Propulsion*, **26** (10, Pt. 2), 19S (*Oct.*, 1956). Products of Perkin-Elmer Corp.

(515) **A method for calculating impact points of ballistic rockets.** S. F. Singer and R. C. Wentworth. *Jet Propulsion*, **27**, 407–9 (*April*, 1957). A simple method facilitated by graphs giving time of flight between two chosen points of the trajectory.

(516) **Tracking camera photographs details of missile flight.** G. L. Christian. *Aviation Wk.*, **67** (17), 110–1, 114 (28 *Oct.*, 1957). Describes 24 in. dia. camera, with focal length 4 to 8 ft. and its mounting and performance.

(517) **Trajectory programming for maximum range.** G. Leitmann. *J. Franklin Inst.*, **264**, 443–52 (*Dec.*, 1957). (4 *refs.*)

(518) **General variational theory of the flight paths of rocket-powered aircraft, missiles and satellite carriers.** A. Miele. *9th Internat. Astronaut. Congr.*, 24 pp. (1958). General equations are presented for analysing the optimum flight paths of these vehicles, assuming a spherical Earth and accounting for the variation in g with altitude. Particular attention is then paid to some special classes of trajectories in the case of a flat Earth (corresponding solutions for a curved Earth will be dealt with in a future paper).

(519) **Summary report of Corporal E, autopilot.** R. P. Gaunt and R. J. Parks. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept.* 4–117, 30 pp. (*Dec.*, 1949).

(520) **Inertial guidance.** W. Wrigley, R. B. Woodbury and J. Hovorka. *Inst. Aeron. Sci., Sherman M. Fairchild Publication Fund, Paper FF-16*, 69 pp. (*Jan.*, 1957).

(521) **Inertial guidance for Air Force high-punch missiles.** J. M. Slater. *Missiles and Rockets*, **2** (4), 77–9 (*April*, 1957). Basic principles.

(522) **Report on controls for Corporal E (Sperry Gyroscope Co.).** *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–15, 93 pp. (*June*, 1946).

(523) **Reports on controls for Corporal E (Sperry Gyroscope Co.).** *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–15 (*Addendum*), 16 pp. (*July*, 1947).

(524) **Stability areas of missile control systems.** W. Haeussermann. *Jet Propulsion*, **27** (7), 787–795 (*July*, 1957). Derives areas of stability for missile control systems with linear and non-linear servo components. Shows methods of adapting signal phase shifting networks to the properties of the missile and a selected servo system. The investigations are extended to missile motion about its centre of gravity, and its prescribed line of flight. (5 *refs.*)

(525) **Inertial navigation.** N. F. Parker and C. P. Greening. *Interavia*, **12**, 575, 577 (*July*, 1957). The principles of inertial navigation described.

(526) **Report on controls for Corporal E (Sperry Gyroscope Co.).** *Calif. Inst. Tech., Jet Prop. Lab. Rept.* 4–36, 15 pp. (*Sept.*, 1947).

(527) **Equipment for missiles.** *Aeroplane*, **93**, 427 (13 *Sept.*, 1957). Photographs of missile guidance and control components.

(528) **Thor guidance goes on production line.** *Aviation Wk.*, **67** (26), 38–41, 44 (30 *Dec.*, 1957). Illustrated article showing some components.

9—RADIO AND ELECTRONICS; COMMUNICATIONS

(529) **Jet Propulsion Laboratory FM-FM telemetering system.** A. Richardson. *Amer. Rocket News*, **1** (1), 13 (*Feb.*, 1957).

(530) **On the use of photoelements in artificial Earth satellites.** W. Berger. *Raktech. u. Raumforsch.*, (1), 22–3 (*April*, 1957). (*In German.*) (4 *refs.*)

(531) **New telemetry era for I.C.B.M.'s and space flight.** H. P. Steier. *Missiles and Rockets*, **2** (4), 37 (*April*, 1957). Account of papers presented to the 1957 National Convention of the Institute of Radio Engineers in New York on the subject of telemetry.

(532) **Navy researchers utilize Moon as communications relay station.** E. Clark. *Aviation Wk.*, **67** (10), 41 (9 *Sept.*, 1957). Notes on some observations of signals reflected from the Moon's surface. Aerial array described.

(533) **Electronics reliability.** G. G. Brown and R. J. Dennis. *Missiles and Rockets*, **2** (10), 172–6 (*Oct.*, 1957).

(534) **Telemetry for tomorrow.** H. P. Steier. *Missiles and Rockets*, **2** (11), 149–152 (*Nov.*, 1957).

(535) **Space communications tested with X-17.** H. P. Steier. *Missiles and Rockets*, **2** (12), 121–2 (*Dec.*, 1957).

(536) **Terrier electronic reliability.** R. R. Yost and F. Dreste. *Missiles and Rockets*, **2** (12), 114–7 (*Dec.*, 1957).

(537) **Electric power for space flight.** J. H. Huth. *Rand Corp. Rept. P*-1244, 16 pp. (10 *Dec.*, 1957). (17 *refs.*)

12—SPACE LAW; SOCIOLOGY

(538) **The international situation and legal involvements with respect to long-range missiles and Earth-circling objects.** A. G. Haley. *Air Force Off. Sci. Res.* (*Feb.*, 1957).

(539) **Space power.** D. Cox. *Missiles and Rockets*, **2** (4), 65–9 (*April*, 1957). Discusses national sovereignty in the upper atmosphere and outside it, and the military advantages of the conquest of near space.

(540) **Space law and law outside the Earth.** A. G. Haley. *Weltraumfahrt*, **8** (2), 57–62 (*May*, 1957). (*In German.*) (12 *refs.*)

(541) **International control of outer space.** D. W. Cox. *Missiles and Rockets*, **2** (6), 68–71 (*June*, 1957). Review of theories of space control.

(542) **Space law and law outside the Earth.** A. G. Haley. *Weltraumfahrt*, **8** (3), 69–74 (*Aug.*, 1957). (*In German.*) (20 *refs.*)

(543) **Law must precede man into space.** A. G. Haley. *Missiles and Rockets*, **2** (11), 67–70 (*Nov.*, 1957).

(544) **The law of space.** M. Aaronson. *Flight*, **72**, 889–90 (6 *Dec.*, 1957). Reviews the international laws controlling the flight of aircraft, and considers the modifications made necessary by the advent of spaceflight.

(545) **Principles for a declaration with regard to the juridical nature of the Moon.** A. A. Cocca. *9th Internat. Astronaut. Congr.*, 4 pp. (1958). (*In German.*) The legal status of the Moon is considered; it is not a zone in space and cannot be considered independent of terrestial states, or declared autonomous or sovereign. There are no property rights on the Moon. A declaration for submission to the national states has been drafted.

(546) **The problem of a definition of "Air Space."** J. C. Cooper. *9th Internat. Astronaut. Congr.*, 10 pp. (1958). Considers the problem of defining the upper boundary of national "airspace." Various suggested solutions are discussed and proposals for new international agreements dealing with flight control are indicated.

(547) **The internationalization of outer space and the unification of the world astronautical strategy: the ecumenical nature of astronautics.** F. A. Pereira. *9th Internat. Astronaut. Congr.*, 3 pp. (1958). Proposals for the establishment of an International Commission of Outer Space.

(548) **The need for a new system of norms for space law and the danger of conflict with the terms of the Chicago Convention.** M. Smirnoff. *9th Internat. Astronaut. Congr.*, 5 pp. (1958). The Chicago Convention cannot serve as the basis for the regulation of outer space. A new conference should create a common system of rules applying to airspace and outer space. The basic law of outer space should be freedom of passage, with the necessary provisions for sound and reliable transport activities, for safeguarding the legitimate interests of States, and for the free development of the science of astronautics.

13—MISCELLANEOUS

(549) **Education—for the missile age.** K. R. Stehling. *Missiles and Rockets*, **2** (1), 50–1 (*Jan.*, 1957). Stresses the necessity for closer cooperation between the universities and research firms.

(550) **Cold facts on a hot seat.** N. Baker. *Missiles and Rockets*, **2** (3), 99–100 (*March*, 1957). The use of a rocket sled to test rocket-actuated ejector seats.

(551) **Plastic balloons in the rocket age.** O. C. Winzen. *Missiles and Rockets*, **2** (3), 50–2 (*Mar.*, 1957). An account of the assistance plastic balloons of up to 5 million cubic foot capacity can give in attaining great altitudes. Multi-stage rockets, rocket aircraft, or observation platforms are described or suggested as suitable loads.

(552) **The world's fastest railway.** H. McLean. *Skyline*, **15** (1), 42–7 (*Spring*, 1957). The Cook sled for testing parachutes.

(553) **Test tracks bring flight problems to earth.** *Jet Propulsion*, **27**, 422–4 (*April*, 1957). Review of tracks and their uses.

(554) **The Rocketdyne boom.** *Missiles and Rockets*, **2** (4), 73–5 (*April*, 1957). Description of the firm, its history and organization.

(555) **Five years of the "Deutsche Arbeitsgemeinschaft für Raketentechnik."** *Weltraumfahrt*, **8** (2) 49–52 (*May*, 1957). (*In German.*) Photographic record of the constructional achievements of this group.

(556) **Five men in a shack.** *Interavia*, **12** (8), 803 (*Aug.*, 1957). An account of the interests and facilities of Rocketdyne, a U.S. firm developing high-thrust liquid propellent rocket motors.

(557) **Rocket-maker Dan Kimball.** *Missiles and Rockets*, **2** (8), 77–8 (*Aug.*, 1957). Interview with Kimball, largely on solid propellents.

(558) **Visit to S.E.P.R. at Villaroche.** *Weltraumfahrt*, **8** (3), 79–80 (*Aug.*, 1957). (*In German.*)

(559) **Rocketeer Sam Hoffman.** *Missiles and Rockets*, **2** (9), 90–1 (*Sept.*, 1957).

(560) **Patrick Air Force Base today and tomorrow.** E. Bergaust. *Missiles and Rockets*, **2** (9), 76–80 (*Sept.*, 1957).

(561) **Rocket sled experiments.** A. Zaehringer. *Missiles and Rockets*, **2** (11), 96–7 (*Nov.*, 1957).

(562) **Rocketdyne develops missile engines now studies space.** *Aviation Wk.*, **67** (21), 86–7, 89, 92, 95, 97–9 (25 *Nov.*, 1957). Description of the facilities existing at this firm, some of their achievements and reference to current work.

(563) **5th Anniversary of the Deutschen Arbeitsgemeinschaft für Raketentechnik.** *Weltraumfahrt*, **8**, 117–9 (*Dec.*, 1957). (*In German.*)

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